ASSESSMENT OF THE MEANS FOR ESCAPE AND SURVIVAL IN OFFSHORE EXPLORATION DRILLING OPERATIONS

Prepared for the Royal Commission on the Ocean Ranger Marine Disaster by Hollobone Hibbert and Associates Limited.

June 1984

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1. INTRODUCTION

This report has been prepared for the Royal Commission on the Ocean Ranger Marine Disaster by Hollobone Hibbert and Associates Limited of London, England under the terms of a contract awarded on 5 October 1983. Environmental data has been supplied under sub-contract by NORDCO Limited of St Johns, Newfoundland.

The objective is to assess critically the means for escape and survival following an emergency incident associated with Eastern Canada offshore exploratory drilling operations and to provide a perspective on practical possibilities to improve these means.

The study has been principally concerned with semi-submersible drilling units but has also considered jack-up rigs, drill ships, helicopters and supply vessels. It has assumed that an emergency incident has resulted in a requirement to evacuate the rig, supply ship or helicopter.

The principle on which the study has been conducted has been to supplement the in-house knowledge of the study team with discussions with relevant company representatives, researchers and others closely involved with aspects of the subject and detailed literature research. The report stems from the results of this extensive research.

The conclusions of the report can be found in Section 2. In essence, they can be looked upon in three groups. First, it is broadly concluded that, with presently deployed abandonment and survival means, the percentage frequency of environmental conditions outside the capabilities of abandonment systems is considerable in areas off Newfoundland in the period from December to March. In particular, wave heights which are excessive for abandonment can be expected for 25% to 46% of the time in some locations during this period.

Second, improvements which are under development are likely to improve abandonment and survival capabilities to a marked degree. Third, no current developments will overcome all the limitations of current systems, particularly in the field of transfer of survivors from survival systems to safe havens.

Throughout our research, the importance of training has been a recurring theme. Our conclusions had to be based upon the assumption that those involved are properly trained in both theory and practical operation of the means of abandonment and survival and that the means are therefore effectively used at the right time. The last point, concerning time of use, is important, involving, as it does, the necessary level of knowledge and experience of those in charge to recognise and correctly react to a potential emergency.

For the purposes of this report, abandonment is defined as 'the act of evacuating a stricken unit from the time of those doing so first taking action to evacuate it until the time when they are clear of it either in a helicopter, floating craft or the sea'. Survival is defined as 'the maintenance of life of those who have abandoned a unit into the sea or floating craft until the arrival of suitable rescue facilities'.

We are grateful to all those people who have given of their time to discuss with us aspects of the study about which they have particular knowledge. We trust that the report justifies their willingness to do so.

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2. EXECUTIVE SUMMARY AND CONCLUSIONS

2.1 SUMMARY

The basis on which this report examines the means of abandonment and survival from MODUs, supply ships and helicopters off the East Coast of Canada is as follows.

2.1.1 Situations Leading to Abandonment

First, the situations which could give rise to a need to abandon such units are assessed in Section 3. In semi-submersible drilling rigs, these are concluded to be:

- structural failure resulting from collision or from design or other intrinsic fault

- stability loss resulting from incorrect ballasting or loading of consumables

- fire, either of a normal ship type or resulting from a blow-out

- unignited gas following a blow-out.

In jack-up drilling rigs, the same situations prevail except that stability failure while jacked up could also result from penetration of a leg through the sea bed surface, usually termed a punch through.

Drill ships are subject to similar causes of abandonment as semi-submersibles though the manner in which they are manifest is often different and they are manned by seamen who are more likely to survive a maritime emergency situation than are landsmen.

Supply vessels have the normal problems of ships but, because much of their cargo is transferred at sea, particular stability problems are introduced. Furthermore the need for them to operate very close to other units, often for prolonged periods, introduces extra likelihood of collision. Off Eastern Canada a further threat to stability is the possibility of heavy icing of the exposed areas, and the possibility of pooping.

Helicopters either crash, that is to say enter the sea in a completely uncontrolled manner, or ditch, when they enter it with some control. In the former case, the chances of survival are slim indeed. In the latter, crews and passengers may well survive the actual ditching and rely then upon successful abandonment and their subsequent ability to survive.

2.1.2 Factors Affecting Abandonment

From the assessment of the situations which may lead to abandonment can be devised an indication of the likely types of conditions with which successful means of abandonment must contend. With these in mind, the factors which affect abandonment are examined in Section 4. These are divided into four groups, namely

- Environmental
- Physiological
- Mechanical
- Human

Each of these is examined in relation to its effect on abandoning MODUs, supply ships and helicopters off the East Coast of Canada.

The environmental conditions off Eastern Canada are divided into five blocks in which they are similar. These blocks represent geographical and seasonally

linked areas. In general terms, throughout the whole area, examination of historical data indicates typical severe storm conditions varying area by area broadly between the following limits:

- Maximum Wind speed 50 to 70 knots
- Maximum Wave height 6 to 17 metres
- Minimum Air temperature -20° to +11°C
- Minimum Sea temperature - 1.8° + 5°C
- Risk of cloud ceiling under 300ft or visibility less than ½ mile between 15% and 45%

Some icing can be expected in the course of the year in all areas.

Burning oil or gas, heat from flares and unignited gas from blow-outs can all introduce particular hazards to abandonment.

The main physiological factors affecting successful abandonment concern respiration, bodily injury and damage to the heart. The factors which could cause each of these are examined in relation to abandonment.

Mechanical factors affecting the success of abandonment systems are next examined. It is concluded that all MODUs may still provide sufficient security to justify an expectation of successful abandonment up to deck angles of 40° with the horizontal.

Based on current designs, it is concluded that abandonment should be possible from the following heights which represent the height above sea level of relevant decks in the vessels concerned:

-	Supply ships	5 metres
-	Drill ships	7 metres
-	Jack-up MODUs	3 metres (in transit)
		20 metres (on site)
-	Semi-submersibles	35 metres (in transit)
		15 metres (drilling)

In helicopters the exit doors may be as much as one metre above or below the surface.

Any power needed by abandonment systems must be available without dependence on the parent unit.

Abandonment systems must be capable of ensuring safe transit of survivors from the point of entry into them to a position clear of the parent unit. Several forms of obstruction can prevent this, ranging from parts of the parent structure, either in way of direct entry to the water or through abandonment craft being swept on to them, to incorrectly working equipment such as release gear for survival craft. Precedent suggests that existing systems are particularly prone to various forms of obstruction.

So far as provision for abandonment by all those onboard units is concerned, it is concluded that, when assessing the optimum number and distribution of abandonment systems it should be assumed that:

- In semi-submersibles and jack-up MODUs, two adjacent sides could be unavailable as a site for abandonment.

- In drill ships either one side or the complete forward, after or midships section cannot be used for abandonment.

- In supply ships and helicopters one side is unavailable for abandonment.

In addition, arrangements for abandoning MODUs should cater for all those onboard the unit including 10% as stretcher cases.

The total time available to abandon vessels, including mustering, preparing equipment and abandonment by total unit complements in likely emergency conditions is assessed to be:

- MODUs : twenty minutes

- Supply ships : thirty seconds providing preparatory precautions are taken early where capsize is deemed a particular hazard. For other causes of abandonment, twenty minutes.

- Helicopters : three minutes.

The simplicity and robust nature of abandonment systems is concluded to play an important part in the effectiveness of abandonment systems, as is the training which users have received about their operation. This training should be both theoretical and 'drill based'.

The availability of means of communication between relevant people during abandonment is deemed to play an important role. In particular they should link the following:

- the parent unit control room
- each abandonment point
- each abandonment craft (if applicable)
- each receiving unit (if applicable).

2.1.3 Criteria for Abandonment

In Section 5, the criteria for abandonment systems are summarised to provide a simple yardstick against which any system can be measured.

2.1.4 Factors Affecting Survival

In Section 6, the factors affecting survival are assessed in the same manner as were those affecting abandonment in Section 4. The main groups of factors are:

- Physiological
- Environmental
- Human
- Rescue factors

Survival in the sea off Eastern Canada is most threatend by drowning, which results from lack of sufficient buoyancy and protection, possibly aggravated by lack of bodily control through injury or, most likely, cold. The latter causes hypothermia which gradually reduces a person's ability to help himself as his core temperature drops until, when it reaches about 26°C, he dies, if he has not drowned first. It is concluded that, if a man is to stand a good chance of survival, his core temperature must not be allowed to drop below 35°C or at worst 33°C. It is concluded that the difference in time taken for a person's core temperature to reach this level in water temperature of 5°C and -1.8°C is immaterial, compared with the differences stemming from other variable factors such as:

- the person's mass to surface area ratio
- the amount of sub-cutaneous fat
- the person's physical fitness
- his general mental state.

It is assumed that survivors in the water would be rescued either by helicopter or by rescue vessels stationed in the vicinity. The response times which could be considered feasible are assessed and from them it is deduced that rescue from the water should be possible within four hours. Accordingly, it is

necessary to ensure that core temperatures of survivors are prevented from falling at more than 0.5C° per hour. It is recognised however that it may sometimes be impossible for those abandoning a unit in emergency to don a full survival suit. It is therefore prudent that provision of relatively cheap 'second line' 'throw away' suits at all abandonment points should be made and that these suits retain reduction of core temperature to 1C° per hour. If this were accepted, core temperature could have dropped to 33°C after four hours which, though causing deterioration in the condition of the wearer, should still leave him revivable.

Further physiological effects of immersion in cold air and water which are assessed are:

- cold shock
- freezing cold injuries
- non-freezing cold injuries
- cold incapacitation

The effects and prevention of the following are also considered:

- lack of nutrition
- inability to breath normal fresh air
- sea sickness
- burns
- body fluid loss

In considering the environmental factors which affect survival, those examined in Section 4 are examined plus sea temperatures, gales and storms. It is concluded that in typical severe storms, sea temperatures vary between -1.8°C and +14°C, that gales can last for between at most 12 and 48 hours and that storms last at most between 4 and 15 hours in different areas off the Eastern Canadian Coast.

The importance of training in survival and in particular education in the principles of survival is stressed.

The necessary communications needed by survivors during the survival phase and to assist in rescue are assessed, together with the requirements for location of survivors and their transfer to safety.

2.1.5 Criteria for Survival

The assessment of factors affecting survival contained in Section 6 is used to compile a list of criteria for survival systems in Section 7.

2.1.6 Assessment of Abandonment and Survival Systems

In Section 8, abandonment and survival systems are assessed against the criteria drawn up in Sections 5 and 7. The objective is to see whether existing systems and those under development can be expected to provide for safe abandonment and survival from MODUs, supply ships and helicopters in the Eastern Canadian Offshore Sector. Where they can not, current limitations which could cause this and, where environmental factors are concerned, the likely frequency of excessive conditions are assessed.

Because the number of different versions of the various types of equipment and systems available and under development for abandonment and survival is in many cases considerable, each one is not assessed against the criteria. Instead, the approach adopted in five main types of abandonment and survival systems is first discussed. These are:

- Evacuation by helicopter
- Dry transfer
- Rigid survival craft
- Inflatable survival craft
- Individual abandonment and survival

The alternative systems which may be, and often are, adopted in each type are described and the chief operating parameters of each are set out. These descriptions are used as a basis for assessment of each main system (and in the case of rigid survival craft, several different types of system) against the abandonment and survival criteria. The basis of the assessment is explained throughout and its results are summarised in two Tables (Tables 7 and 8). The meaning of the results of this assessment is then examined in detail and this leads to conclusions which are themselves summarised below.

2.2 CONCLUSIONS

2.2.1 Helicopter Evacuation

This provides the most satisfactory first line means of abandoning offshore units if sufficient response time is available (up to four hours); if the units are not listing beyond the limits of the helicopters involved; if fire or gas are not hazards and, perhaps most limiting of all, if visibility is sufficient. The frequency of the latter being the case varies from 97.5% of the time in one case in one month and area to as little as 61.7% of the time in another area and month. Visibility limitations can be overcome by fitting SAR designated helicopters with equipment which has already been developed for military use and is currently available fitted to some civilian helicopters.

2.2.2 Dry Transfer

Several dry transfer systems have been designed and would, if effective, provide an excellent means of abandonment and survival. To be effective in the sort of conditions prevailing off Eastern Canada, they would need a dedicated receiving vessel and so, on financial grounds, do not lend themselves to use by isolated MODUs and are not designed for supply ships or helicopters.

2.2.3 Rigid Survival Craft

Current craft of this type depend for successful abandonment on their launching systems. They are unlikely to be launched successfully into wave heights over 8 metres or wind speeds over 50 knots. This limits their use off Eastern Canada to an appreciable degree. In particular, in areas off Newfoundland, the frequency of such conditions in the months of December to March varies from 25.3% to 46.2%. Such existing systems are also subject to limitations imposed by mechanical failures, particularly of release gear. Many of these limitations can be overcome by systems which are either available or under development. The free fall lifeboat system extends the wave conditions under which launch is safe to 9 metres (and probably, though not yet proved, to considerably more) and overcomes some other limitations.

The 'PROD' system, if proved, is likely to extend the wind and wave height conditions appreciably, maybe making launch possible under all normal environmental conditions in the area. It does not, however, cater for launch from the upper side of a heavily listing unit.

The 'Lifescape' system is expected to extend wave height limitations to about 12 metres.

In each of these systems, except possibly the 'Lifescape', it is advisable for survivors to wear full survival suits to protect themselves against the effects of cold.

No existing systems provide entirely satisfactory communications, location arrangements and means of transfer of survivors to safety while at sea. Suitable equipment is available to overcome the first two deficiencies but not the last.

2.2.4 Inflatable Survival Craft

These craft are looked upon as subsidiary systems following helicopter evacuation or rigid survival craft. They do not provide sure means of abandonment in poor weather conditions though, if abandonment can be achieved, they may well provide some protection in all conditions likely to be encountered in the area. They offer no protection against fire or irrespirable gas and to avoid the effects of cold, survivors must wear proper survival suits. They are ill equipped for communication, location and transfer of survivors to safety. In spite of these considerable limitations, however, they have a role to play as a 'last resort' system.

2.2.5 Individual Abandonment Systems

Survival suits are available which fulfill the physiological criteria for survival, though only a prototype hood to protect survivors from drowing has so far been produced. However, communications and transfer to safety present problems which are even more acute in the location of individual survivors.

Though special means exist to assist individuals to abandon MODUs, none have been found which would be effective in the adverse weather conditions found off Eastern Canada. Because individual abandonment is likely to be a last resort, probably taken as a unit sinks, the most important thing is to be protected by a suitable survival suit.

2.2.6 Helicopter Abandonment and Survival

Survivors from ditched helicopters rely on survival suits and life rafts. They are therefore subject to the same limitations as have been described for these types of equipment and so may not survive for more than about four hours in the waters off Eastern Canada unless the conditions make it possible to enter their life rafts successfully and at an early stage. The nature of survival suits used by those in helicopters is likely to differ from those used by people abandoning MODUs and supply ships, to reflect the different circumstances.

2.2.7 Supply Ships

Providing sufficient warning is available, abandonment of supply ships off Eastern Canada should be possible in the conditions normally found. Survival would be subject to the same limitations as in other situations discussed.

3. ABANDONMENT SITUATIONS

3.1 INTRODUCTION

The need to abandon a unit, be it a ship, a helicopter or a MODU, can arise from a number of causes which are detailed in Sections 3.2 to 3.6 below. Although the causes are varied the end result may fall into one of two categories: the unit either becomes untenable because of fire or other hostile environment, or it becomes in danger of sinking.

The events leading up to these states of affairs are examined in order to assess the likely situation existing during the abandonment phase, thus enabling criteria for the abandonment systems to be determined.

It should be noted that the object of this part of the study is not to carry out detailed risk analyses but rather to attempt to build up pictures of likely conditions which may prevail when units are at risk to a point where abandonment may be necessary.

Since the situations in some instances vary considerably with ship, helicopter and each type of MODU, they are treated separately in the following paragraphs.

3.2 SEMI-SUBMERSIBLE DRILLING RIGS

3.2.1 Structural

A structure may fail as a result of an external cause, for example a collision with a supply ship, a larger vessel in transit or even an iceberg, or it may fail as a result of an intrinsic fault, for example poor design (including fatigue), bad workmanship, or badly designed or badly executed modifications. These are examined below:

- Collision - Although minor collisions between supply ships and MODUs have been recorded on a number of occasions, no instances in open sea operations have been found where damage to a rig has been sufficiently serious to cause concern for its safety, although seventeen instances of structural damage to fixed platforms in the North Sea by supply vessels are on record between 1966 and 1981[1].

  In most instances the damage to the supply vessel tends to be the more serious and there has been a number of instances where ships have suffered severe flooding as a result of contact with drilling installations, though such incidents mainly involve fixed platforms.

  It may be stated with confidence that the risk of catastrophic damage to a semi-submersible rig by a supply vessel is remote. If it did occur the result would almost certainly be gradual flooding because of holing resulting in the unit very gradually listing and eventually sinking. There should be several hours available to take action before the list became so severe as to make work about the deck difficult. With damage from this cause to a rig built to the present MODU Code[2], sinking would only result through ballasting failures.

  It is also remotely possible that a supply ship may penetrate sufficiently far inside a rig's structure that a heavily stressed structural member may be damaged sufficiently for it to fail, in which case the result would be similar to that discussed below. No evidence that such an accident has yet occurred has been found.

  A collision with a large ship in transit would almost certainly be catastrophic although fortunately there do not appear to be any such incidents on record and

therefore the likelihood is remote. The high incidence of fog in the area under review, which could increase this likelihood, is probably offset by the relatively low density of marine traffic.

If such a collision were to occur, enormous damage would probably be done, immediately resulting in parts of the rig capsizing and sinking before there was much time for anyone to take sensible or pre-planned action to save himself. The risk must obviously be greater in busy shipping lanes and though several studies have been and are being carried out into such risk in British, German and Norwegian waters, no evidence has been found of any such studies covering the area under review.

Collision with an iceberg is a possibility in spite of the precautions taken to avoid it. The effects could vary from minor damage to capsize or sinking.

- Design or other intrinsic fault - Under this group of problems, are included original design, poor workmanship or badly designed or executed modifications.

  Broadly speaking, if a member fails as a result of fatigue and this failure then becomes progressive, until there is a major structural failure, the basic design is inadequate because the structure does not have sufficient redundancy built into it, as was the case of the 'Alexander L Kielland'

  By experience, a structural failure for whatever reason is one of the more likely causes of a semi-submersible rig sinking. The likelihood of a rig being lost as a result of structural failure is being reduced by the various regulatory bodies, as experience is gained, mainly by requiring a rig to remain stable and buoyant

even though a major part of the structure may have failed. However this cause must still pose one of the more serious threats. A major structural failure is a dramatic event in that the major part of the rig remaining usually becomes unstable in its designed attitude and immediately takes up a new attitude in which it is at least temporarily stable. This new attitude will probably involve an immediate list of 30° or so or perhaps even more. Depending upon the arrangements to prevent down-flooding into columns and deck area the rig may either remain stable for hours, days or even weeks at this new angle, or it may rapidly increase its angle of list until it finally capsizes. This happened in the case of the Alexander L Kielland, which immediately assumed a list of about 30°. Rapid down-flooding occurred and the list increased to about 50° over a period of about twenty minutes, at which point the rig capsized and sank.

3.2.2 Stability

Reduction in stability stems from two main causes. These are:

- Ballasting - It may be said that all of the foregoing cases result in the rig being unstable at one point or another. However in these cases stability, or lack of it, is not the prime cause.

  The ballast system can be a prime cause of loss of stability of a rig either as a result of its failure, or its mis-operation, or a combination of both. Although only one rig is thought to have been lost primarily as a result of ballasting problems, there have been, and no doubt will be more occasions where ballasting problems have occurred but have been corrected without serious results, and are therefore not generally known.

- <u>Loading of Consumables</u> - In many ways this problem is inextricably tied up with that of ballasting. Fuel, drilling fluids, bulk chemicals, tubulars and all the other materials consumed or stored onboard a unit must be loaded strictly in accordance with the stability data. Careful weight control is needed throughout the life of a unit to avoid an accumulation of deck weight. During loading and back loading, the ballast control room must be quite specific about what goes where and appropriate corrections to ballast must be made both during loading and during discharge down the hole. Any misunderstanding on the part of the deck crew or controllers, misinterpretation of instructions or break down in communication can be the initial cause of a stability problem. Having said this, even a quite serious list can usually be corrected provided the ballast system is working correctly, is designed to operate at the angle to which the list has progressed and the operators have a sound knowledge of both ballasting principles and of the system on the rig.

One of the problems related to stability is that the MODU Code[2] only specifies that ballast pumps should be able to operate at 15° angle of heel or 7½° angle of trim (though coastal states, including Canada, often set more stringent standards). It is in some cases not difficult to exceed these angles. In the event of a serious and progressive stability problem occurring it is unlikely that capsize and sinking would be rapid. Most semi-submersible rigs are designed with considerable excess stability and can therefore normally cope with such situations though at some drafts stability reserve becomes limited. Unfortunately, because of the many different configurations, it is not possible to say clearly how far any semi-submersible will heel safely, since each configuration must be calculated separately. However it is safe to say that, should a progressive stability problem occur, one could expect

several hours to elapse between initial indication that a problem exists and final capsize.

Experience would suggest that the probability of losing a rig as a result of ballasting problems alone is remote if it is built to the present MODU Code[2] as laid down and without exemptions.

3.2.3 <u>Fire</u>

The types of fire which can lead to abandonment are:

- <u>Internal Fire</u> - This is a ship type fire as opposed to a blow-out or leak of hydrocarbon gas. A ship type fire would involve either fuel oil or other flammable substances held on board, or domestic materials such as sheets, mattresses and so on. It could be started from a wide variety of causes, even including a helicopter crash.

  It is very unlikely that a fire of this nature would warrant abandoning a rig though in the case of a serious fuel oil fire it may be considered prudent to remove non-essential personnel as a precaution and in order to facilitate fire fighting. Fires of this sort, though infrequent, are not uncommon.

- <u>External Fires</u> - This category includes a blow-out of gas or oil which has caught fire, or an accumulation of well gas in a confined space which has caught fire or exploded. This latter category would very soon become a ship type fire if it persisted and would be treated as such.

  The former would be the more serious and action would depend very much on individual circumstances. In all cases it would almost certainly be deemed prudent to remove non-essential personnel. If it was considered

that there was a chance of controlling the blow-out with means at hand and it was possible for men to remain on board, then this would probably be done. It could well be decided to winch the rig off the well if this was possible. However if the blow-out was major and, for example, burning oil was being spread over a wide area, an attempt would almost certainly have to be made to abandon. A blow-out of gas would be slightly less of a problem because there would be no fire on the sea. Radiant heat however would be very considerable.

Blow-outs of both oil and gas are not uncommon. Thirteen have been reported in MODUs worldwide since 1968[4], although no information has been found about how many resulted in fire.

3.2.4 Unignited Blow-out

A blow-out of either oil or gas would represent enormous potential for injury in the event of it catching fire. This would take the following forms:

- Oil Blow-Out - A serious oil blow-out would quickly spread a film of oil over the surrounding water and if it was light oil there would be a very serious risk of fire. Provided there was a little wind or current there could well be one side of the rig which remained relatively clear but it would of course be the 'upwind' side.

- Gas Blow-Out - With a major gas blow-out the seriousness would depend very much on climatic conditions prevailing at the time. If the day was windless and the humidity very high then a cloud of gas would probably form around the rig with the attendant problems of respiration or the possibility of a 'flash fire'.

Unignited blow-outs are also not uncommon. However, a dangerous concentration of unburnt gas surrounding an offshore rig is unusual since conditions of 'no wind' rarely exist. As previously stated, thirteen blow-outs have been reported on MODUs worldwide since 1968[4] although no information has been found about how many resulted in fire.

3.2.5 In Transit

A semi-submersible rig in transit is under some circumstances more vulnerable than a rig which is securely moored. With the exception of the very few rigs which have full dynamic positioning capability there is seldom enough power to cope with heavy weather and tug wires are liable to part. Connecting a new wire takes time and is often hazardous and difficult. If the shore or other hazards are to leeward there is always the risk of stranding or collision. For this reason it is often worth taking a little longer on passage in order to give the shore or other hazards a wide berth. A rig which is only partly moored when the weather worsens to a point where the mooring or unmooring operation cannot be completed is in a particularly vulnerable situation. Tugs, rig propulsion, or a combination of both must be used to ease the strain on weather moorings still laid. If some moorings part it may be necessary to slip those remaining, thus leaving the rig adrift and with only a limited number of anchors to deploy in an emergency.

A rig at the deballasted transit draft must be ballasted down to survival draft in the event of bad weather. Under some conditions of loading the rig becomes less stable during this operation and it may be necesary to dump liquids or chemicals.

The foregoing examples have been used to illustrate the particular problems of a rig in transit and to reinforce the view that on a long or difficult move, or on one made during unsettled weather, it is worth considering removing as many personnel as possible who are not immediately concerned with the move.

Actual abandonment of a free floating rig does not usually present any particular problems beyond those of a moored rig, unless it has been driven ashore, is in surf and helicopters are not available.

3.3 JACK-UP DRILLING RIG

A jack-up rig differs from all other units under consideration in that during the drilling phase it is in contact with the sea bed and in fact relies upon the sea bed for support.

3.3.1 Structural

As in the case of a semi-submersible, a structural failure may be the result of a collision or an inherent defect as follows:

- Collision - The risk of catastrophic damage to a jack-up rig as a result of a collision with a supply ship is not great. Collisions have occurred but no record of a modern jack-up rig collapsing as a result of such an occurrence has been found.

  A collision with a large vessel in transit could well be catastrophic. However, no evidence of such an occurrence has been found. The risk in some of the waters in question, particularly off Nova Scotia, will no doubt be increased as a result of the predominantly foggy conditions during spring and autumn.

- Design or other intrinsic fault - Problems stemming from a structural weakness in a jack-up rig are almost always of leg origin. It may be the construction of the leg itself or it may be the jacking or locking mechanism.

  In the event of a leg collapsing either as a result of its own structure failing, or the jacking or locking mechanism failing the result is similar - one part of the rig is no longer supported and will probably fall towards the sea. The rig will then assume a new attitude with one edge of the hull in the sea down to main deck level and the other edge supported by the remaining legs. The angle of the deck from horizontal will probably be 30° or greater.

  If the weather is calm the rig may stay in this position for several hours or even days.

  One of two things could happen to cause total collapse - these could be either progressive flooding of the hull until it eventually sank, or failure of the other legs as a result of being subjected to bending stresses for which they were not designed. Apparently 'Sea Gem' took about thirty minutes to collapse totally and 'Mallard Rig 35' in which a leg collapsed in the Gulf of Mexico in 1978 also took a similar time. Although rules cannot be laid down as a result of observation of only two accidents, this time would seem to be reasonable.

3.3.2 Stability

Loss of jack-up unit stability can result from two main causes which are :

- Sea Bed Support - A jack-up rig whilst on location is unlike any of the other cases considered in that it relies upon the support it receives from the sea bed rather than its own buoyancy and correct ballasting to keep it on an even keel for working. A cause of accidents has been the penetration of jack-up legs through a hard layer just beneath the sea bed into a soft layer beneath that (punch through). This soft layer is incapable of supporting the weight carried by the leg and the result is very similar to failure of jacking or locking mechanism or structural failure of a leg mentioned in the preceding paragraph. This sort of accident can be avoided by making sub-sea bed surveys including shallow seismic or core sampling of the upper layers of the sea bed[5].

  A further problem connected with sea bed support is uneven distribution of load over the foot of the leg as a result of a non-level surface. If this happens, all the load is taken by one edge of the foot, causing a bending load to be imposed upon the leg in the direction away from the supported edge.

  An uneven surface may have one of two causes. The first is a condition which was there before the rig came along, for example a slope, a rock or wreckage, probably of a ship. This sort of condition can be avoided by carrying out a sea bed survey either by side-scan sonar, magnetometer or visual means by diver or vehicle in good time before the rig moves onto a location[5].

  The other reason for uneven support can be scour. Particularly if the sea bed is predominantly of sand, strong tidal streams or currents flowing round the foot are likely to remove particles of sea bed away from one side of the foot, thus once again resulting in uneven support and consequent bending stresses being set up in

the leg. The result may again be the same as for a structural failure. Precautions to be taken under these circumstances include frequent visual inspections and placing sand bags around the foot if scouring is found to be occurring.

A recent survey[5] listed twenty-one accidents thought to be the result of sea bed failures.

- <u>Material Loading/Discharge</u> - Taking on board materials, usually from supply vessels, and discharging materials, usually down the hole, must be carefully controlled in much the same way as on board a semi-submersible rig. Instead of upsetting the ship type stability, the structural loading will be upset. Overstressing of parts of the hull, legs or leg locking mechanism can result in the risk of failure of the overstressed part.

  The bearing pressure of the 'foot' of a leg upon the sea bed will increase and the leg may begin to sink until the load decreases. This in turn will result in the other legs becoming overloaded and a general 'out of balance' between legs or differential penetration will occur, again with a risk of failure.

  It is worth noting that a constant vigil on leg loading is necessary to avoid overstressing as a result of uneven weight distribution. This is because there is always some settlement and it is often uneven. This is in spite of pre-loading of legs immediately after moving onto location. When this happens it is necessary to use the jacks to even up the loading and level the rig.

3.3.3 <u>Fire</u> As in 3.2.3, except that it is not usually possible to winch a jack-up rig off the well because of the need to first jack down.

3.3.4 <u>Unignited Blow-out</u> As in 3.2.4.

3.3.5 In Transit A jack-up rig has its own problems in transit. It is ungainly, not sea-kindly and is unlikely to be self-propelled. The legs in a deep water rig tower high over the derrick and present considerable windage. It is difficult to control in confined waters in heavy weather. Since the jacking operation also presents hazards it is again worth considering removing non-essential personnel over long and difficult moves.

Abandonment of a jack-up rig in transit differs from the jacked up situation in that deck height above water would be much less (about 3 metres as opposed to 20 metres). If planning or layout have not been given careful thought, the skidded, or laid down derrick, or other stored materials, may obstruct access to life saving appliances and because of the height of the legs, or for other reasons, the helipad may be unmanable, or may be subject to restrictions.

3.4 DRILL SHIP

A drill ship will be subject to the same basic problems as a semi-submersible rig but there are differences. In particular it has a ship type hull and can therefore be expected to behave like a ship rather than a semi-submersible or a jack-up, each of which have distinct peculiarities. Furthermore, a drill ship will carry a great many more mariners in its complement than other types of MODU. This is important.

3.4.1 Structural

Structural failure leading to abandonment is only likely to result from collision. Collision with a supply ship, a vessel in transit or ice are considered. As in the previous cases, it is considered unlikely that a supply vessel collision would cause

sufficient damage to a drill ship to result in the vessel sinking in view of the manner in which it is divided into watertight compartments. A collision with a large vessel in transit could well however result in disaster, particularly if the drill ship is struck on the beam. Under these conditions the drill ship could be cut in two. A head-on or stern-on collision could be less serious. A collision with an iceberg is likely only to drive the ship off position.

Serious damage in a collision with a large vessel would result in rapid flooding of the affected areas after which the vessel (or two halves thereof) would either sink, capsize or become stable again, probably with a marked list or trim, much as any other vessel.

The important difference when comparing a drill ship with either a semi-submersible or jack-up unit is that the former is virtually a ship and will behave like one. It could list to at least 50-60° before capsizing. The height from which the lifeboats, liferafts or men singly must enter the water will be much less than for a semi-submersible or jack-up rig. Conventional ship-type life-saving appliances were developed for just such a situation and without further development should be expected to be more effective than on a semi-submersible. A further important difference is that drill ships are manned by seamen who are more likely to survive an emergency situation at sea than are landsmen. This was borne out in the Alexander L Kielland disaster[6].

3.4.2 Stability

Much of what has been written about semi-submersible stability in section 3.2 applies to drill ships with one or two important exceptions. For example, the ballast system is operated by mariners who would be

expected to have a satisfactory understanding of its operation and the effects of its mal-operation since they are dealing with a ship and will be familiar with the principles involved. The deck officers carry out stability calculations and adjustments to ballast are made at their instruction by the chief engineer (or his subordinate).

Actual stability characteristics of a drill ship will follow very much the same characteristics as any other ship and although all vary a little, a well designed ship would be expected to heel to 50° or more before the righting moment was lost and capsize occurred. These figures would apply to a drill ship.

Distances from deck to sea level and therefore distance from which survival systems must safely enter the water could be much less than for a semi-submersible, that is seven metres as opposed to thirty five metres.

3.4.3 Fire As in 3.2.3.

3.4.4 Unignited Blow-out As in 3.2.4.

3.5 SUPPLY VESSEL

A supply vessel is basically a ship, with the problems typical of a ship. However there are also additional problems. Large cargoes are discharged at sea requiring speedy and radical changes of ballast to keep the vessel on an even keel. Some early supply ships had serious problems in this respect because it was impossible to correct trim if all cargo from one end of the ship was discharged. It was therefore necessary to retain some cargo on board or take a trim by the head (bows down, stern too high in water). This affected handling and sea keeping performance generally.

The other additional problem is that most ships avoid large objects at sea. A supply ship's task requires it to remain within a few feet (fifty or so) of a rig for several hours in weather which may be far from good. Modern supply ships are now usually fitted with fore and aft side thrusters of much higher horse power than hitherto, and either joystick control or occasionally full dynamic positioning. This is very different from their predecessors which had to rely on much less horse power to their main propulsion of twin screws and a single bow thruster, frequently of inadequate power. All these units had separate controls.

The large machinery and bulk cargo spaces in older ships were single skinned and several ships got into difficulty after being holed by a projection from a rig just below the surface of the water. In this respect too the situation has changed in that ships are now virtually double skinned in these areas by having side tanks for fuel and water built in. The steering flat is normally isolated and there are tanks in the after-peak and fore-peak.

Deck cargo is carried as routine by these ships because of the requirement to discharge at sea, which prevents holds with hatches being used. If equipment is backloaded from the rig in marginal weather it is not always possible to secure it as well as it should be secured. It may therefore break loose and all slide to one side of the deck. Part cargoes of tubulars are very prone to this if they are not slung in bundles before loading.

All the foregoing adds up to the fact that although supply ships are ships in all senses of the word and basically behave like ships, they do have additional problems and these are quite likely to manifest themselves close to the rig.

3.5.1 Structural Damage

Structural failure which could lead to abandonment of a supply ship is only likely to result from collision. It is not proposed to discuss the outcome of a collision with another ship. This would most probably happen a long way from the rig and would be treated in much the same way as any such collision.

A collision with the rig of sufficient magnitude to cause serious flooding, would nowadays be exceptional in view of improved hull designs and it is considered unlikely that the ship would sink quickly. It is much more likely that a list would develop which may be aggravated by cargo already on board which could not be moved. Present damage stability requirements state that it should be possible to flood two adjacent small compartments or one large compartment without the vessel sinking. However, there may be additional factors adversely affecting the situation. It is not considered likely under these circumstances that capsize and/or sinking would be rapid. If a list developed, it could go to 50° or 60° before the ship capsized. It is therefore thought reasonable to believe there would be enough time to abandon ship in an orderly manner using the ship's own life saving appliances. It may even be possible to return to port.

It is considered so unlikely that a modern ship should fail as a result of design or other inherent fault that it is not proposed to include such a possibility in these considerations.

3.5.2 Stability

Three main causes of severe loss of stability in supply ships are envisaged. These are:

- Cargo Shift - As mentioned previously, this can be a problem and has been a contributory cause of supply ship losses in the past. Movement of a cargo which is inadequately secured can and has capsized ships. This is particularly likely in heavy weather. The recent capsize of Seaforth Jarl bears this out.

  A capsize from such a cause can be very quick, the only warning being that the cargo is beginning to move. There may not even be minutes available to take action.

- Pooping - Their low freeboard aft makes supply ships more vulnerable than many other vessels to pooping. This has been the cause of these vessels foundering more often than other ships[7]. Good ship handling (matching speed and course to wave conditions) and proper securing of doors and hatches should prevent this cause of stability loss. If it occurs, foundering is likely to happen quickly.

- Ice - The dread of cold climatic areas can form extremely quickly, although not normally so quickly that no action can be taken. If such conditions materialise it is usually prudent to attempt to leave the freezing area, probably by steering a southerly course. Another useful piece of advice given by ship masters operating in Canadian waters is to steam hard through heavy weather rather than slowly, since the spray associated with slow steaming freezes much more readily than the green water associated with hard steaming. Much, of course, will depend upon the state of the sea and the strength of the vessel.

  A capsize due to formation of ice on the superstructure of a ship will be sudden. The point will be reached when the top weight will become so great that when the ship rolls it will not recover, but will continue over until inverted. The only warning will be that a rapid

build up of ice will take place and the movement of the ship will 'feel' very tender.

3.5.3 Fire

It is very unlikely that a ship would be caught up in a well-associated fire though it could conceivably steam into a gas cloud which may then be ignited by a spark from the ship. However this is considered so unlikely that it is only proposed to consider a ship type fire.

A ship type fire requiring abandonment of a supply ship would be very unusual but could occur. It would be progressive and would probably develop relatively slowly to the point where abandonment was deemed necessary. Although certain areas would no doubt be inaccessable there should be time to abandon ship in an orderly fashion. The ship would very probably be on an even keel.

3.6 HELICOPTERS

Unlike all other units considered, a helicopter does not start in the water, it arrives there by accident for one of two basic reasons: it either ditches, that is it lands on the water in a controlled fashion, or it crashes. The circumstances considered and therefore the headings under which they are addressed will also be different from previous headings.

The statements in this section are based largely on discussions held with senior representatives of British Airways Limited, supplemented by study of accident reports.

3.6.1 Ditching - An aircraft ditches because the captain decides that problems exist which would probably cause the aircraft to descend out of control (ie crash) if he

did not land it on the water under control. He does this with the full knowledge that, certainly if the sea is at all rough, his own and his passengers' lives are being put at risk as a consequence. He makes this decision because he considers that not to do so would put all on board at even greater risk.

One cause of S61s ditching which has occurred on more than one occasion has been the loss of gear box lubrication in spite of an auxiliary lubrication system which is fitted. An S61 gear box, like that in most other modern helicopters including the Super Puma, will operate satisfactorily for at least five minutes without oil before seizing up. A Chinook, which is a larger and more modern design, has two separate lubrication systems which should individually be capable of lubricating satisfactorily. In the event of the failure of both systems up to two hours can be expected before catastrophic gear box failure occurs.

Another reason for ditching is loss of power, that is failure of all engines for some reason. In this case there is less time and the impact on the water may be greater because the helicopter must be put into auto rotation and 'free wheel' down without power. At the end of the descent, to soften the touch down, the pilot uses the inertial energy of the rotor system to land, which requires fine judgement.

Having descended safely and landed upon the water the captain must then decide what must be done next. If the sea is calm and the helicopter has an amphibious hull he may decide to remain on board until help arrives. Both the S61 and the Chinook have amphibious hulls but their sea keeping qualities vary. The S61 relies upon sponsons for stability in the water and if these have been damaged during landing a capsize is very probable even if the sea is relatively calm.

Lateral stability and augmentation of natural amphibious qualities are improved in the UK by the addition of pop out floats on the outboard sides of the sponsons. If all is intact and a sea anchor deployed an S61 is able to tolerate waves of up to 5 metres in height although much depends upon other factors too. The steepness of the sea is important; in waves with a height/length ratio less than 1:11 the sea anchor gets pushed towards the helicopter by oncoming wave crests and allows the head to fall away until the line once again becomes taut. In steepness of 1:9 the sea anchor is frequently pushed back under the hull and is totally ineffective, thus allowing the hull to go beam on to the wind and waves.

The Chinook is much more stable in the water than the S61 and under some circumstances can tolerate waves of up to 10 metres in height. These figures are taken from model test data since full size trials have not been carried out except at very low sea states. Model tests also showed that an S61 would take between 1½ and 8½ seconds to capsize. Ideally the rotors should be kept turning after water landing but this is not always possible because mechanical problems are usually the cause of a ditching. Certainly with an S61, the chances of it floating upright for any length of time in any sort of sea state are unlikely. If the sea is very rough a quick capsize is almost inevitable.

No other helicopters currently in commercial use have amphibious hulls. They must therefore rely upon inflatable flotation bags. These must be inflated as the helicopter is landing in the water. If they are inflated too early, they are liable to be torn off on impact. If they are left too late then the helicopter can either capsize or remain upright in a stable position. The operating mechanism for the bags is normally kept in a 'disarmed state' in order to avoid

unintentional inflation during normal flight which can be disastrous. If in the heat of the moment the pilot forgets to 're-arm' them they will not inflate when he 'presses the button'. If this happens they will be inflated automatically after submersion since they have an additional inflation device with a salt water activated switch but inflation will be rather later than ideal.

The situation may be summed up as follows: if the sea is calm and the helicopter has an amphibious hull the chances are that it will remain floating and upright for hours, perhaps even days. If the helicopter does not have an amphibious hull the chances of it remaining upright are less, but it still may do so for a short time and it will in any case most probably remain afloat.

As the weather becomes rougher the chances of even an amphibious hull remaining upright become poorer until if it is very rough there is hardly any chance at all. The wreck will, however, in all probability float for several hours, perhaps even days, because of either inherent or added buoyancy.

Provided everyone is correctly strapped in there should be no serious injuries during or immediately after the ditching. Most helicopter ditchings, certainly all North Sea ones, have been carried out without any loss of life though in at least one instance, when an S61 ditched in rough seas in October, the captain, who was rescued after 53 minutes and who was wearing only a shirt and uniform trousers had become semi-conscious when picked up. He lapsed into unconsciousness on the flight back. He was unable to help himself though he had spent the entire time in the water holding an injured passenger's head clear of the water. Medical opinion was that if he had not been rescued within a few minutes he would have lost consciousness completely

and would have drowned. He remembered nothing of being winched up and upon arrival in hospital his body core temperature was 33°C.

3.6.2 Crashing - Helicopters may crash for at least two reasons. The first is a catastrophic failure, usually of the main or tail rotor system, and the second is either pilot error, disorientation or subtle failure of an instrument leading to misinterpretation in conditions of poor visibility, whilst flying very low. In either case impact with the water is probably violent, usually resulting in the immediate sinking of the fuselage.

Catastrophic failures normally result in a crash with total loss of life.

In a crash caused by pilot error or inaccurate instrument readings, the chances of survival may be a little better because the helicopter will probably hit the water in a more or less straight and level attitude and, although the impact would cause severe damage and almost immediate sinking, there would be a chance that at least some of the passengers would be able to escape from the hull as it sank. A recent accident off the Scilly Isles in the United Kingdom resulted in the bottom being virtually ripped out of the hull and its almost immediate sinking. Four passengers and the two pilots were able to get out as the hull sank to a depth of 200 ft and all six survived, though the remaining twenty people on board were killed.

A Bell 212 operating in the North Sea recently crashed as a result of pilot disorientation whilst it was involved in low level inter-rig flights. Despite the fact that it was not an amphibian, it floated for a period partially inverted, the buoyancy being from one of the flotation bags. Of a full complement of crew and passengers, there was only one fatality due to drowning.

Section 3 References

1. 'Review of Repairs to Offshore Installations' - UEG Report No UR21.

2. 'Code for the Construction and Equipment of Mobile Offshore Drilling Units' - published by IMO.

3. 'The Capsizing of Alexander L Kielland' - Sigmund Rusaas. Second International Conference on Stability of Ships and Ocean Vehicles - Tokyo - October 1982.

4. 'Risk Assessment of Emergency Evacuation from Offshore Installations'. Study for UK Department of Energy by Technica.

5. 'Some Thoughts on Jack-Ups East Coast Canada' - Noble Denton and Associates Inc.

6. 'Evaluation of Emergency and Sea Rescue Techniques for use from Mobile Offshore Drilling Units in Canadian Waters'. Martec Limited, page 2.36.

7. Statement in correspondence with Ship Safety Branch of Canadian Coast Guard.

4. FACTORS AFFECTING ABANDONMENT

4.1 INTRODUCTION

In the previous section, the causes of need to abandon MODUs, helicopters and supply vessels have been examined. From this examination, conclusions have been drawn about the possible effects on the conditions of materials and personnel. These form part of the basis for assessment of the factors affecting abandonment of such units. Other inputs to this assessment come from environmental, physiological and human factors. The inter-relationship of the factors is summarised in Figure 1 below.

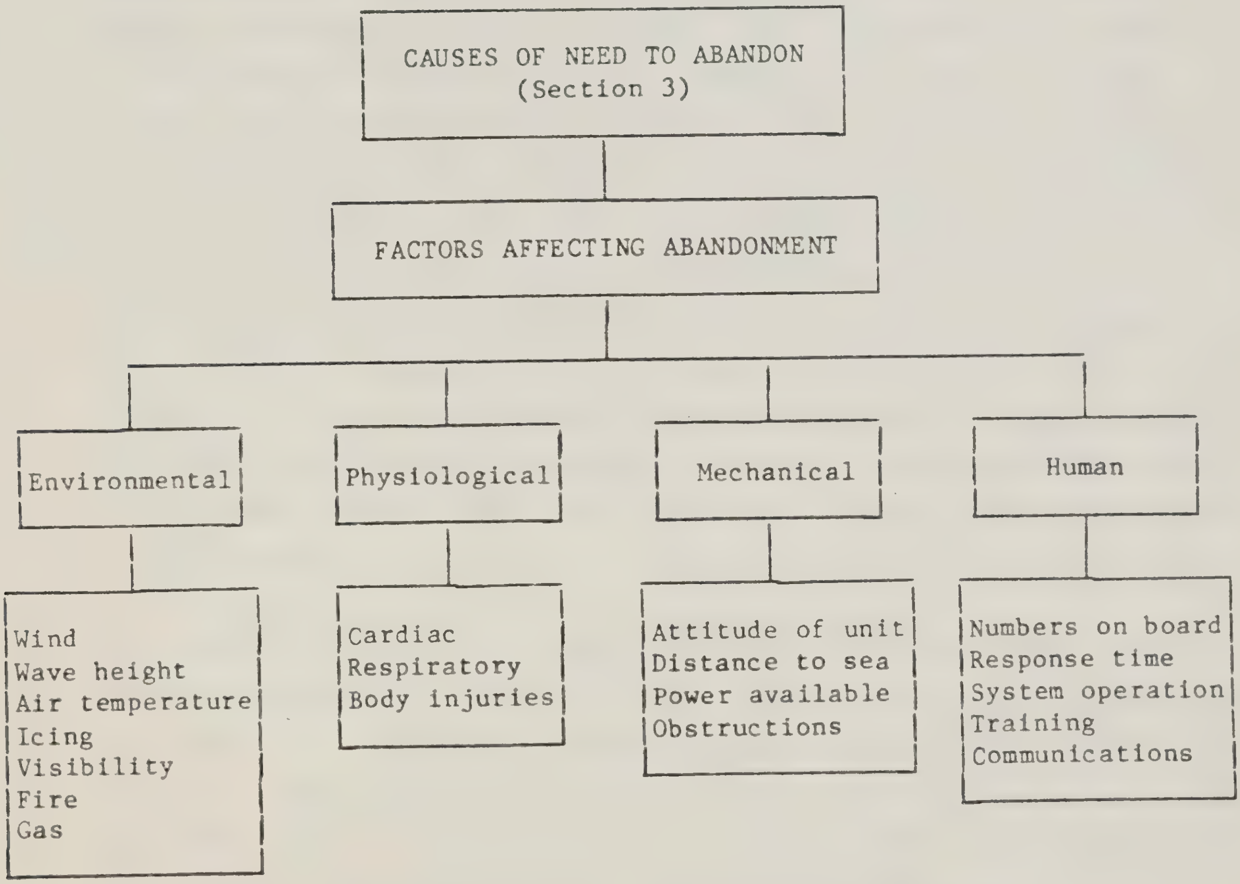


FIGURE 1 INTER-RELATIONSHIP OF CAUSES OF ABANDONMENT AND FACTORS AFFECTING ABANDONMENT

The factors affecting abandonment are examined in the following paragraphs. From them, the criteria for abandonment systems are deduced in Section 5.

4.2 ENVIRONMENTAL

The environment in which abandonment takes place is of great importance to the manner in which it is attempted. The effects of the environment are discussed in other paragraphs in this Section. The purpose of this paragraph is to set out the environmental conditions which must be catered for by abandonment systems.

In providing environmental criteria for abandonment and survival systems, several approaches to the use of statistical environmental data are possible. To use the 100 year extreme values is sensible for design criteria for installations which are intended to be subject to any environmental conditions for prolonged periods. However it would attempt to set a level of preparedness which is unreasonably demanding when seeking to guard against the worst effects of an event which all the efforts of designers and operators seek to avoid ever happening. For reference purposes, however, the 100 year extreme events are contained in Appendix B. Good data are available for mean values of environmental conditions and these are shown in Appendix C for reference purposes. However, here again, the use of these values as criteria for abandonment and survival systems would not be suitable because, by definition, there is a 50% chance that an emergency would occur in worse conditions.

To provide realistic and practical criteria, the environmental conditions used in this report represent historical records* of typical severe storm conditions season by season. They are contained in full in Appendix A. The maximum wave heights are derived from 1.7 times the historical significant wave height figures.

*Note the principal sources of these records are computer tapes of marine meteorological observations for the North

Atlantic (all observatios to 1980); meterological reports from drilling rigs off the Canadian East Coast 1980-83; US Navy Marine Climatic Atlas of the World Vol I, 1974; Unpublished paper by W Raina 'Offshore Environmental Hazards', 1983.

In Appendices A, B and C data are listed for 14 geographical areas. These are shown in figure 2 below. They have been chosen as representing areas with similar climatological conditions and with similar types of drilling activity. The seasons shown are defined as:

Summer - June - August
Autumn - September - November
Winter - December - March
Spring - April - May

4.2.1 Weather Factors

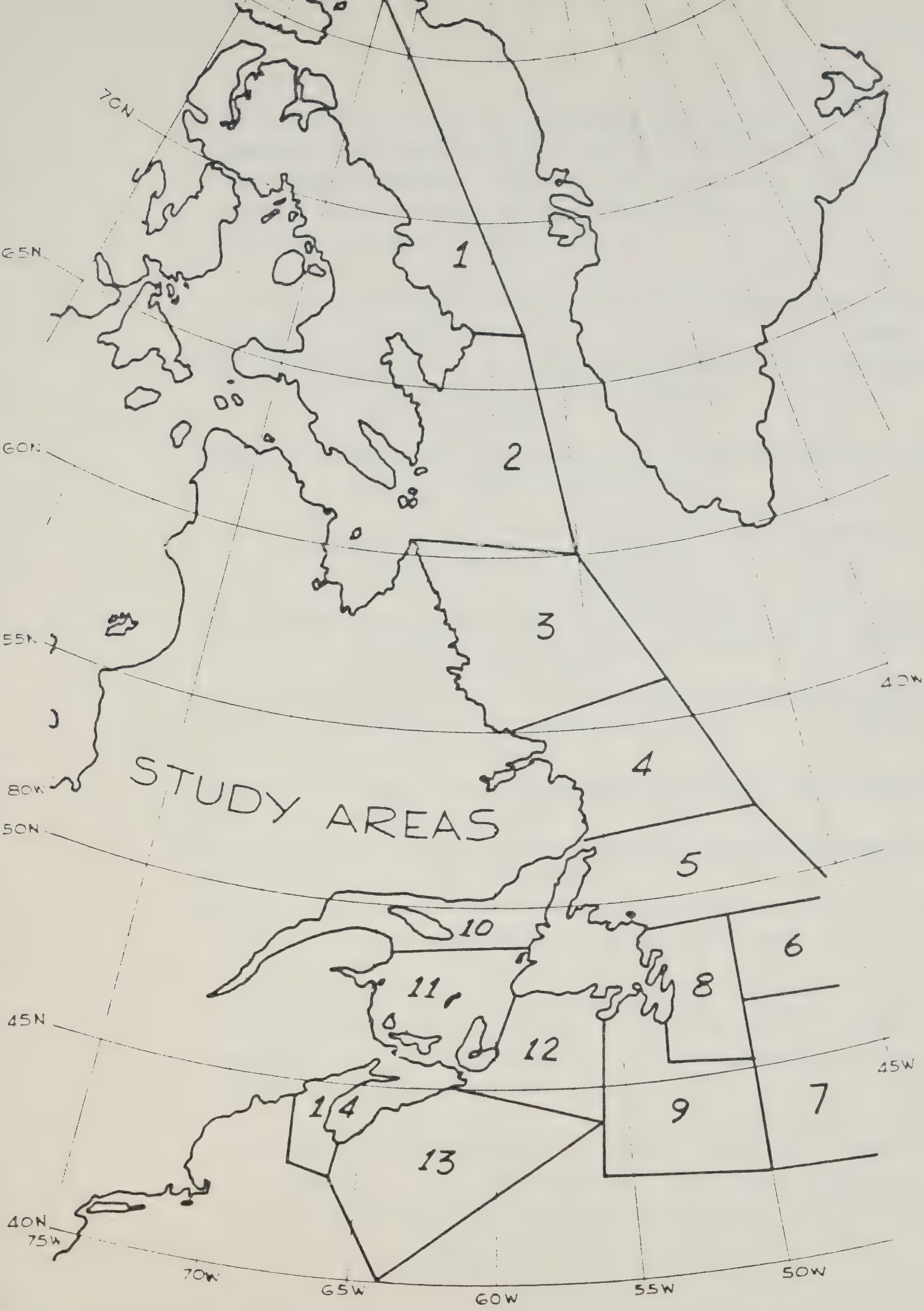
The main weather factors which affect abandonment are wind, wave height, air temperature, icing and fog. All of these except icing are addressed in Table 1 below, which sets out 'blocks' of similar typical severe storm conditions linked geographically and seasonally. It should be noted that they do not, for the reasons expressed above, represent the extreme conditions possible. It should also be noted that some areas are excluded due to ice cover, which prevents drilling operations of the type under review.

BLOCK	TYPICAL SEVERE STORM CONDITIONS	SEASONS/AREAS
A	Max wind 50-60 knots Max wave height 6-10m Min air temp -2° to +5°C Ceiling 300' or vis ½ mile for under 30%	Spring 9-14 Summer 1-4
B	Max wind 50-60 knots Max wave height 6-10m Min air temp +1° to +11°C Ceiling 300' or vis ½ mile 15-45%	Summer 5-14 Autumn 9-14
C	Max wind 50-65 knots Max wave height 14m Min air temp +1° to +2°C Ceiling 300' or vis ½ mile 25-30%	Spring 6,7,8 Autumn 6,7,8
D	Max wind 60-70 knots Max wave height 12-17m Min air temp -4°C - 8°C Ceiling 300' or vis ½ mile 20-30%	Winter 6,7,8, 9,12,13,
E	Max wind 55-70 knots Max wave height 7-9m Min air temp -7° to -20°C Ceiling 300' or vis ½ mile 15-30%	Winter 10, 11,14

Table 1. Typical Severe Storm Conditions

In broad terms, severe storms conditions vary area between the following limits:

- Max wind 50 - 70 kts
- Max wave height 6 - 17m
- Min air temperature -20° - +11°C
- Cloud ceiling less than 300' or visibility 15 - 45% of the time.



Environmental Areas Off Eastern Canada Figure 2

Icing of structures and equipment can add considerable problems to abandonment of units, particularly MODUs and supply vessels. The incidence of icing likely in typical severe storms in the areas shown in Figure 2 is forecast in Table 2 below.

AREAS	ICE FORMATION	SEASON
1,2	Light (severe sea ice cover Spring, Autumn and Winter)	Summer
3,4	Occasional light (severe sea ice cover Spring and Winter)	Autumn
5	Nil (severe sea ice cover Spring and Winter)	-
6,7,8	Occasional Occasional light in gales, severe to very severe in storms	Spring Winter
9,12 9,12	Likely Likely in gales, severe to very severe in storms	Spring Winter
10,11	Moderate to severe in gales, very severe in storms	Winter
13,14	Occasional light in gales, moderate to severe in storms	Winter

TABLE 2 OCCURRENCE OF ICE FORMATION

Table 2 shows that some icing can be expected during severe storms in the course of the year in all areas except Area 5, though this area suffers severe sea ice cover in Spring and Winter.

Two other environmental factors can also affect abandonment. These are fire and gas cloud which may stem from the cause of the need to abandon.

4.2.2 Fire

Several aspects of fire must be taken into account when considering abandonment systems.

All MODUs are designed to flare off gas during well-testing. The radiant heat from flares is not insignificant and must be taken into account when designing and siting abandonment systems.

Loss of well control (blow-out) resulting in escape of oil or gas into the local atmosphere is one of the potential causes of a need to abandon a MODU referred to in Section 3. Such accidents occurred on thirteen occasions in MODUs during the period 1968 to June 1982[1] and must therefore be looked upon as a real risk. When this does occur, a high risk of combustion exists and, though attempts would of course be made to avoid the use of abandonment systems affected by the resulting fire, other factors, such as damage or wind and sea conditions may necessitate their use.

Though fire resulting from blow-outs is likely to be the most catastrophic form of offshore fire, fires in equipment, started in a variety of ways from welding to electrical faults, can and do occur. Precautions to avoid spread of such fires to abandonment areas and their effect on abandonment systems are necessary. This applies to both MODUs and supply ships.

Helicopter fires, if they occur, are likely to spread quickly and not all abandonment systems should be subject to their effects. However research has not revealed any cases of helicopter accidents offshore which have involved fire.

In trials on lifeboats in Japan, it was assumed that the lifeboat would be subjected to fire on the sea

surface at a temperature of $1000°C^2$. This temperature can reasonably be used as a basis for assessment of abandonment systems performance in any offshore fire.

4.2.3 Gas Cloud

If gas escapes from a well being drilled by a MODU it presents two particular hazards. The first is the risk of combustion. The second is the risk of poisoning or suffocation.

Abandonment systems of MODUs must be intrinsically safe. It should be impossible for sparks or naked lights to be caused by any items of equipment. Amongst likely sources of such hazard are internal combustion engine exhaust systems, electrical equipment and mechanical equipment where high levels of friction can be generated either in the normal course of operation or through improper operation.

Supply ships and helicopters are most unlikely to be subject to this risk since they could and would be instructed to stay clear of hazardous conditions of this nature.

4.3 PHYSIOLOGICAL

4.3.1 Introduction

During abandonment, those abandoning a unit must be protected from injury. The types of injury to which they may be subjected will vary with the nature of the accident, the prevailing conditions and the type of abandonment system used. However, they can be addressed under three main headings and this is done in the following paragraphs.

4.3.2 Cardiac

Death soon follows cardiac arrest. It is therefore of fundamental importance that abandonment systems safeguard those using them from the causes of cardiac arrest. In the context of the situation under review, these can be summarised as:

- Sudden violent changes in temperature
- Drop of body core temperature to about 28°C
- Severe electrical shock
- Extreme physical exertion in the unfit
- Physical damage to the heart
- Severe bodily injury.

These in effect mean that abandonment systems must ensure that their users are retained in an environment where extremes of temperature are avoided, they are protected from electrical shock, they are not required to over-exert themselves physically and they are protected from bodily injury. The last of these requirements is examined further in paragraph 4.3.4 below.

Extreme changes of temperature are possible during abandonment only if those involved move suddenly from one environment to another. The most likely cause of this is entry to the sea itself. If this occurs, 'Cold Shock' may result, which is described in more detail in paragraph 6.2.3. In considering abandonment, it is enough to say that any abandonment system used offshore Canada must ensure that the area of the body coming into direct contact with sea water is kept to an absolute minimum. Thus, if entering the sea, people must be protected by survival suits. Ideally, suits should exclude water but if they leak, they must not allow ingress of water at more than five litres per hour[3].

Drop of body core temperature below 35°C should be prevented during abandonment as confusion and disorientation, the initial symptoms of hypothermia, will be experienced at this temperature. See figure 3 below.

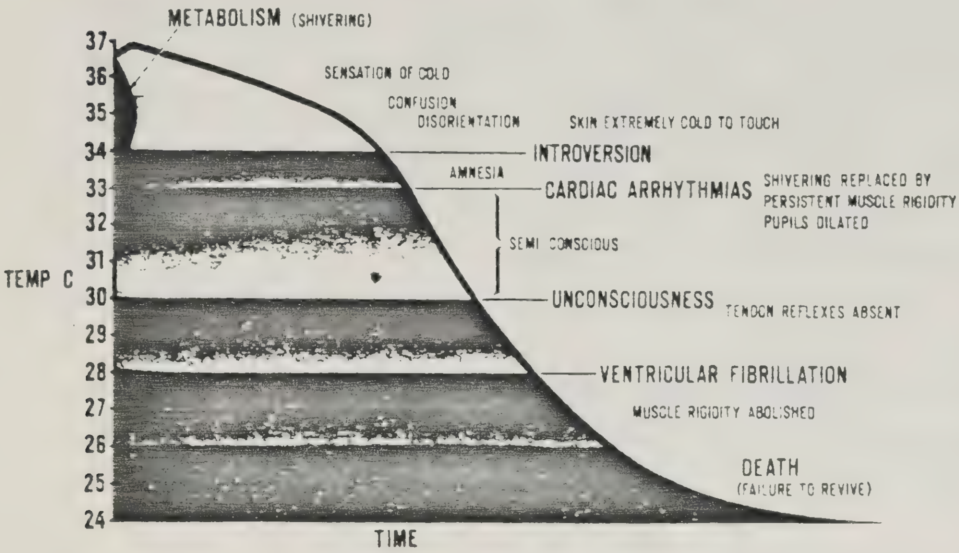


FIGURE 3 CURVE REPRESENTING PHYSIOLOGICAL BEHAVIOUR DURING COLD WATER IMMERSION[4]

Prevention of electrical shock is a fundamental design criterion for any equipment, not only abandonment systems. However in abandonment systems this is made more difficult by the need for them to exist and be operated in very wet environments. One particular source of electrical shock is the winch wire of helicopters. Considerable charges of static electricity can be built up in helicopters which, if not earthed first, can earth through a person touching the winch wire or strop while standing on a deck or floating in the sea.

Extreme physical exertion is most unlikely to cause cardiac arrest if the heart is in good condition and the body core temperature is normal. However, if

survivors suffer from some heart weakness or body core temperature is low it may do so and accordingly any need for such exertion should be avoided.

4.3.3 Respiratory

Unconsciousness and subsequent death will result from failure of the respiratory system or from a person breathing toxic gases. In the context of the situation under review, failure of the respiratory system can result from drowning, some forms of brain injury or severe bodily injury. Injury is examined in paragraph 4.3.4 below.

Toxic gases can pollute the local environment after a gas blow-out on a MODU. They are also generated by internal combustion engines (CO).

Abandonment systems must cater for providing suitable breathing gases for their users in spite of these potential contaminants.

Abandonment systems should also provide means to ensure that users' airways are kept free of water to prevent drowning. In fact drowning during abandonment is unlikely as, by definition, 'abandonment' ends and 'survival' starts when those abandoning a unit are clear of it either in a helicopter, floating craft or the sea. However it is possible that the abandonment system could, of itself, introduce the hazard of drowning during entry to the water and this must clearly be avoided. For example, an individual evacuating a MODU without some form of aid to ensure his safe transit from it into the water could well drown. Likewise, the means of abandoning helicopters and supply ships must take account of this hazard.

4.3.4 Bodily Injury

As mentioned in paragraphs 4.3.2 and 4.3.3 above, severe bodily injuries can cause cardiac arrest or respiratory failure. They can also lead to permanent disability.

Injuries can arise from two main causes - burning and violent impact or acceleration. Fire hazard is discussed in paragraph 4.2.3 above. Violent impact is caused by sudden changes in the relative velocities of people or their limbs and surrounding objects. The objective in all abandonment systems must therefore be to avoid conditions which lead to violent impact or unacceptable accelerations. The tolerance of the body to such accelerations varies with their direction relative to it. The limits of acceleration are shown in Table 3 below.

CRITERIA	Repeated tests		Limits used in design
Acceleration time (sec)	0.1-0.2	0.2-0.5	0.1-0.2
+ Gx (eyeballs out)	16 g	8 g	20 g
- Gx (eyeballs in)	20 g	15 g	20 g
+ Gy (side impact)	10 g	6 g	10 g
+ Gz (eyeballs down)	6 g	4 g	6 g
- Gz (eyeballs up)	16 g	8 g	10 g

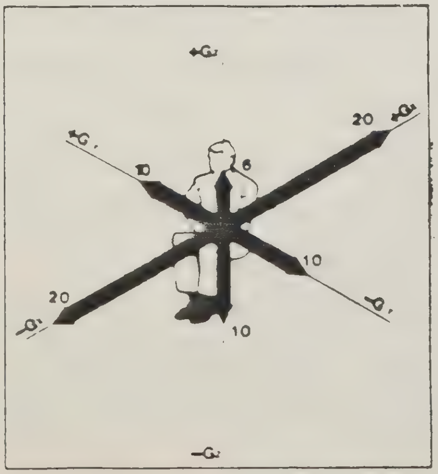


TABLE 3 PHYSIOLOGICAL LIMITS TO ACCELERATIONS

4.4 MECHANICAL

4.4.1 Introduction

Many mechanical factors must be considered in relation to the effectiveness of abandonment systems. The systems must take account of the possible condition of the unit being abandoned. This involves looking back to the possible causes of the need to abandon as well as at the design of the unit itself. These factors are examined in the following paragraphs.

4.4.2 Attitude of Unit

Structural or ballasting failure can cause a MODU or supply ship to take on angles of list or trim or combinations of the two. Helicopters are all to some extent unstable in water.

In considering the behaviour of MODUs, it is necessary to look both at design criteria and the evidence of actual accidents. The stability criteria for semi-submersible drilling units laid down in the MODU Code do not provide any minimum angle of list or trim which which must be acceptable whilst still retaining a righting moment[6]. Each vessel will have different angles, depending upon the details of the design.

A reasonable practical indication of the sort of angles which semi-submersible drilling units may assume before capsize becomes inevitable can be obtained by examination of the results of model tests and calculations carried out since the Alexander L Kielland disaster. It has been deduced from accounts of the accident and by model tests that Alexander L Kielland assumed an angle with the horizontal of 31.1° when the leg was severed. During the next twenty minutes while flooding of internal spaces of the deck structure occurred, this

is thought to have increased to about 50°[7]. The vessel then capsized.

It is unlikely that practical and controlled steps to abandon vessels whose decks were angled at over about 40° from the horizontal could be taken. Though this is 10° less than the angle at which Alexander L Kielland is thought to have lost stability, it can reasonably be used as a target for the design of abandonment systems for semi-submersible MODUs.

Drill ships and supply ships are designed to retain righting moments up to lists of 50° and even 60°. However to carry out controlled movements prior to abandonment when they were listing to these angles, particularly in the moderate to heavy seas which would often be the condition off the east coast of Canada, would be extremely difficult. Accordingly abandonment should occur before this angle of list has been reached and again 40° is considered reasonable.

Jack-up MODUs can conceivably be expected to assume deck angles of up to about 40°. Because accidents leading to such conditions can be very varied it is impossible to be precise in this respect. However, for the same reasons as applied to all other vessels, to cover greater angles would be unnecessary while to choose a smaller angle might not cover all practical eventualities. Accordingly abandonment systems for jack-up MODUs should be designed to operate at deck angles of up to 40° with the horizontal.

As shown in Section 3.6.1, helicopters float in a horizontal position either upright or capsized. If only one flotation bag inflates on ditching, the weight of rotors, engines and gear box at the top of the machine will usually invert it fully against the single bag buoyancy. When capsizing happens it takes between

1¼ and 8½ seconds, thus giving no time for abandonment. Accordingly, in considering abandonment from helicopters, it should be assumed that they are horizontal in either upright or inverted positions. In the latter case, they will soon be almost completely under water.

4.4.3 Deck Height

The height from which abandonment must take place will vary with the design and nature of the unit. The following figures represent typical heights from which life saving craft are launched from existing vessels:

- Supply ship - 5 metres
- Drill ship - 7 metres
- Jack-up MODU - 3 metres (in transit)
  - 20 metres (on site)
- Semi-submersible - 35 metres (in transit)
  - 15 metres (drilling)

These heights provide a reasonable indication of the likely distance from main deck to sea level in each type of vessel. Primary abandonment systems should cater for transporting those using them safely clear of the unit from this height above sea level.

In helicopters, the distance from the exit door to the sea will be at most one metre but could be beneath the surface.

In some circumstances it is possible that abandonment will occur as the unit sinks or from a point at sea level (ie in cases of severe list). This should be taken into account where possible in primary abandonment systems and in what may be considered secondary systems which do not fulfill all the requirements of primary systems but nevertheless fulfill this function.

4.4.4 Power Available

In view of the nature of the incidents which could lead to the need to abandon any unit, it is very possible that no sources of electrical, hydraulic or pneumatic power will be available for abandonment systems from the unit's main supplies. Any such power supplies which are needed must therefore be provided without recourse to the unit's normal supplies.

4.4.5 Obstructions

Obstructions in the way of abandonment systems can take many forms. The principle which must prevail is that no obstructions should interfere with the safe transit of an abandonment system from the point of entry into it to a position clear of the unit.

Obstructions to helicopters can be presented both while airborne and when they are on deck. In assessing the suitability of arrangements for abandonment by helicopter it is necessary to ensure that no masts, aerials, flagstaffs, flare-booms, cranes, guard-rails or other obstructions endanger the helicopter or, if winching procedures are to be used, those being winched. Furthermore, it is necessary to ensure that no protrusions on the deck such as pipes, ventilator cowls or bollards can obstruct a helicopter as it lands or present a hazard to those being winched.

In supply ships, drill ships and jack-up units in transit, obstructions can be presented by items of cargo which have shifted or ill-stowed equipment in the vicinity of abandonment systems. Additionally on jack-up units in transit, the derrick in its skidded or lowered condition could present an obstruction. If abandonment is carried out in rough weather, it is very possible that craft launched into the sea may strike the hull unless means to prevent this are introduced.

In semi-submersible units, obstructions to abandonment systems leading to the sea can be found in columns, pontoons or anchor cables if the vessel is listing or if the abandonment craft is swept onto them by waves. In addition, where craft may effect abandonment by floating off the deck as the unit sinks, obstructions can be found in structural items in their vicinity which have either been allowed to be present by bad design or have collapsed there due to damage.

Obstructions can take the form of malfunctioning equipment. For example, the release mechanisms for falls on lifeboats have several times failed to operate when required, resulting in temporary or complete failure of the abandonment system. In a detailed study of the operation of seven rigid abandonment craft (two Whittaker Capsules and five Harding Lifeboats) in the Alexander L Kielland and Ocean Express incidents in the North Sea and Gulf of Mexico respectively, unsuccessful operation of the release gear was recorded on four occasions[1]. During abandonment by capsule of the Ekofisk Alpha Platform in the North Sea, one capsule was released accidentally when still high above the Sea, killing three people and seriously injuring three more. This risk has therefore been very real and it is essential that whatever means of disengagement from the unit are adopted by the abandonment system, they should be reliable under all circumstances and as foolproof as possible.

Obstructions may be presented by survival clothing. A too bulky survival suit or inflated life-jacket or air entrapped in a survival suit may prevent a man passing through an opening. Buoyancy may prevent him from moving underwater to leave a submerged opening.

4.5 HUMAN FACTORS

In this paragraph the factors affecting abandonment systems are examined which are introduced by the fact that they must cater for both saving and being operated by humans, with all their strengths and weaknesses.

4.5.1 Numbers Onboard

Abandonment systems must of course provide means of abandonment for all the people onboard the parent unit under any foreseeable conditions. This must take account of the fact that some abandonment system units may not be usable for one or more of a variety of reasons. For example, fire may prevent people reaching them or damage may render them unserviceable.

The SOLAS regulations, including the MODU Code[6], lay down standards for the level of redundancy in life-saving appliances in ships which should form the basis for individual nation's own regulations. After the Alexander L Kielland disaster, the Norwegian Commission of Enquiry recommended that there should be accommodation in life boats for twice the number of people as are onboard a MODU at any one time. This exceeds the MODU Code which, in effect, requires accommodation in lifeboats for one and a half times the number on board or in life boats and liferafts for twice the number on board. Canadian regulations demand the latter.

It is conceivable that, for a variety of reasons such as weather conditions or limitations imposed by fire, the attitude of the vessel or conditions at the well, two adjacent sides of any jack-up or semi-submersible MODU could be unavailable as a site for abandonment.

In drillships it must be assumed that either one side or the complete forward, after or midships section cannot be used for abandonment.

In supply ships and helicopters it must be assumed that one side is unavailable for abandonment.

Some people onboard a unit being abandoned may have been injured and, if so, may only be moveable by stretcher. There is no way of knowing how many injured there may be. However some form of precedent is set by the UK Department of Transport in its requirements for standby vessels. There, in its requirements for beds in standby vessels, it assumes that 10% of an installation's complement may be injured[8]. ~~We can see~~ No better precedent than this has been found and accordingly it is recommended that the arrangements for abandonment systems in MODUs should, in addition to following the philosophy described in this paragraph, cater for all those onboard the unit, including 10% of whom are stretcher cases. This requirement is not, however, considered necessary for helicopters or supply ships.

4.5.3 Response Time

The time available to abandon a unit will always depend upon the nature of the cause of abandonment. In the Alexander L Kielland disaster there were about twenty minutes between the collapse of the column, which occurred with no warning, and the total capsize of the unit. With Ocean Ranger there were indications that an emergency could be developing for some six hours before abandonment occurred and the unit did not sink for another two hours thereafter[9]. These considerations have been examined in Section 3 above and lead to the conclusion that, provided warnings of impending emergency are noticed and heeded, the minimum response time available in a MODU is likely to be about twenty

minutes and in most cases it will be considerably longer.

Except when precautionary evacuation is prudent, a sound maxim in maritime emergencies is to remain with the parent unit until it is impractical to do so any longer. Accordingly, any abandonment system should be designed to stay onboard the parent unit as long as possible and operate effectively when the moment to abandon comes. Its operation can therefore be looked upon in two phases, first preparation and then operation. Both should be reduced to the minimum period. The sum of the two when applied to the total unit complement, should not occupy more than twenty minutes for MODU systems.

Supply ships may capsize very quickly. Accordingly, if such an occurrence appears possible, it is all the more important that preparation for abandonment should be made early and operation of abandonment systems should be possible within thirty seconds. For other causes of abandonment however, preparation and abandonment may take up to twenty minutes.

Helicopters which ditch also provide a few minutes warning. A period of three minutes for preparation and abandonment should be available in most cases.

4.5.4 Systems Operation

When abandonment systems are needed, the circumstances will not be conducive to careful, measured actions by those involved. People will be frightened and in some cases injured. They may have to act fast. There could be panic. To reduce the effects of these factors, it is essential that the number of actions required to operate abandonment systems is kept to a minimum, that they should be as simple as possible and that the

possibility of misoperation of any equipment be, so far as possible, prevented. This applies to manual and automatic operations. The likely success of abandonment systems can be measured in terms of the complexity of their operation if in other respects their capabilities are similar.

4.5.5 Training

No

No matter how simple and foolproof a system, those operating it must first be taught what they need to do. When fear and hurry are present they must know instinctively what to do. This can only be achieved by good training under knowledgable mariners which not only explains what to do but why it must be done. For this training to remain effective, it must be repeated in some form from time to time and must include sufficient 'practical' experience to ensure familiarity.

This factor plays a very large part in the abandonment of offshore units. Abandonment systems, if properly designed, will be simple to operate (see paragraph 4.5.4 above). The training required will therefore not be extensive in academic terms but must ensure that those who may use them are fully familiar with the systems and their operation. Naturally, such training should not be undertaken in conditions, or a manner which puts trainees at risk.

4.5.6 Communications

In any emergency, the ability to pass relevant information between all those who need it is of great importance. Until individual abandonment systems are operated, control of abandonment is retained by the senior person on the unit. He must be able to communicate with the person in charge of each abandonment unit to pass instructions and to receive information.

Once the unit has been operated and the abandonment craft is clear of the parent unit, it must be possible for it to communicate with other such units and with SAR forces. These latter communications are discussed in Section 6. However, the equipment used for each purpose could well be common.

Because of the importance of such communications and because of the vulnerability of communications equipment in circumstances of abandonment, it is judged necessary to provide 100% redundancy in communications arrangements. This need not entail simple duplication but could use two different types of communication system.

?, must not

The stations which must be linked by abandonment system communications include all those positions involved with the abandonment such as:

- the parent unit control room
- each abandonment point
- each abandonment craft (if applicable)
- each receiving unit (if applicable).

Section 4 - References

1. 'Risk Assessment of Emergency Evacuation from Offshore Installations'. Study for UK Department of Energy by Technica.

2. 'Fireproof Lifeboats of Reinforced Plastics' - Ship Research Institute of Japan. International Conference on Marine Survival Craft, Liferafts, Lifeboats, Survival Systems - London, November 1983.

3. Conversation with Surg Cdr F St C Golden, Royal Navy.

4. 'Recognition and Treatment of Immersion Hypothermia' - Surg Cdr FStC Golden. Proceedings of the Royal Society of Medicine. October 1973, Vol 66, No 10, pp 10/58 - 10/61 (United Services Section pp 16-19).

5. 'Design of Free-Fall Lifeboat Systems' - P Werenskiold, Norwegian Hydrodynamic Labratories. International Conference on Marine Survivial Craft, Liferafts, Lifeboats, Survival - London, November 1983.

6. 'Code for the Construction and Equipment of Mobile Offshore Drilling Units' - published by IMO.

7. 'The Capsizing of the Alexander L Kielland' - Sigmund Rusaas - Second International Conference on Stability of Ships and Ocean Vehicles - Tokyo, October 1982.

8. 'Assessment of Suitability of Standby Vessels for Attendance at Offshore Installations' - UK Department of Transport.

9. US National Transportation Safety Board Draft Marine Accident Report 'Capsize and Sinking of the US Mobile Offshore Drilling Unit Ocean Ranger off East Coast of Canada 166 Nautical Miles East of St Johns, Newfoundland, 15 February 1982.'

5. CRITERIA FOR ABANDONMENT SYSTEMS

5.1 INTRODUCTION

In the previous Section the factors which affect abandonment of MODUs, supply ships and helicopters have been examined. In this Section, the criteria which must be fulfilled by abandonment systems to take account of these factors are set out. The capabilities of abandonment systems to match these criteria are assessed in Section 8.

The criteria can, in most cases, be equally relevant to abandonment of MODUs, supply ships and helicopters. Where special requirements exist, these are highlighted.

5.2 MECHANICAL

Abandonment systems must meet the following mechanical requirements:

5.2.1 Deck Angle

To ensure safe operation when the deck of the parent MODU or supply ship is angled up to 40° from the horizontal.

In the case of helicopters to ensure safe operation when the helicopter floor is horizontal in either upright or inverted condition.

5.2.2 Deck Height

To ensure safe operation from height above water level of:

- Supply ships - 5 metres
- Drill ships - 7 metres

- Jack-ups - 20 metres
- Semi-submersibles - 35 metres
- Helicopters - 1 metre (both above and below sea level)

Secondary abandonment systems to be capable of operation at sea level.

5.2.3 Power Supplies

To operate safely without recourse to the parent unit's normal supplies of electric, hydraulic or pneumatic power. (NB: The use of external power sources is acceptable for recovery of abandonment units after practice drills).

5.2.4 Obstructions

To be capable of operation in emergency conditions without danger of fouling or being prevented from clearing the parent unit by any obstructions or equipment malfunctions. In the case of individual abandonment, care should be taken not to hinder the progress of those abandoning by excessive bulk or initial buoyancy.

5.2.5 Capacities

To be capable of providing for the safe abandonment of all people onboard the parent unit (up to 10% of whom may be on stretchers*), when two adjacent sides of a jack-up or semi-submersible MODU, one side or the complete for'ard, after or midships section of a drill ship, or one side of a supply ship or helicopter are unavailable as a site for abandonment.

*NB: The requirement for 10% of personnel in stretchers should be waived in the case of helicopters and supply ships.

5.2.6 Response Time

To be capable, in conjunction with other available abandonment units, of preparation and complete operation, up to abandonment to a position clear of the parent unit, of all people onboard MODUs within periods of twenty minutes from the executive instruction to prepare to abandon the unit.

To be capable of ensuring complete abandonment of helicopters within three minutes of the instruction to prepare to abandon.

To be capable of ensuring complete abandonment of supply ships within twenty minutes of the instruction to prepare to abandon. To be capable (by primary or secondary means) of ensuring safe abandonment in thirty seconds if preparation has already been made.

5.2.7 Systems Operation

To be designed to be operated by system users as simply as possible and to be mechanically as simple and fool proof as practical, commensurate with effective operation.

5.2.8 Air Temperature

To be capable of safe operation and protection of users in minimum air temperatures of -20°C. This requirement includes the provision of means to operate safely in conditions of severe icing of exposed areas and, when in the water, in conditions of brack ice.

5.2.9 Wave Height

To be capable of safe operation in conditions where maximum wave heights of up to 17 metres exist.

5.2.10 Wind Speed

To be capable of safe operation in wind speeds of up to 70 knots.

5.2.11 Visibility

To be capable of safe operation in zero visibility. // By touch

5.2.12 Fire

To be capable of safe operation and protection of users for short periods in areas of fire, with temperatures of up to 1,000°C and of operation at any time in conditions of radiant heat from normal sources such as flares. This requirement does not apply to helicopter systems. ?

Additionally, persons proceeding to an abandonment point should have protection to enable them to pass quickly through a flash fire.

5.2.13 Gas

To be capable of safe operation in irrespirable or combustible gaseous environments. This requirement does not apply to supply ships and helicopters. ?

5.2.14 Accelerations

To operate normally without subjecting users' bodies limbs or organs to positive or negative accelerations exceeding those shown in Table 3 in paragraph 4.3.4.

5.3 OPERATIONAL AND ENVIRONMENTAL

Abandonment systems must meet the following requirements:

5.3.1 Training

Only to be operated by people who have received proper theoretical and practical instruction in their operation. Instruction and practice in their use should be given to all potential users. Systems to be designed to be capable of recovery after drill launching.

5.3.2 Communications

To provide at least two means of communication between abandonment systems and all positions involved with abandonment such as, but not limited to:

- The parent unit control room
- Each abandonment point
- Each abandonment craft (if applicable)
- Each receiving unit (if applicable).

5.3.3 Temperature Changes

To prevent rapid and extreme changes of temperature being applied to the body surface of users. Ingress of water inside protective clothing should be avoided and should always be less than five litres per hour.

5.3.4 Environmental Temperature

To ensure that users are maintained in an environment such that their core temperature does not drop below 35°C. The environment itself should not exceed a temperature of 35°C.

5.3.5 Electric Shock

To prevent the application of electrical charges to users in such a way as to cause electric shock.

5.3.6 Extreme Physical Exertion

To avoid the need for extreme physical exertion by users.

5.3.7 Breathing Systems

To ensure that a suitably respirable atmosphere is maintained under all circumstances and that users' airways are always kept free of water.

6. FACTORS AFFECTING SURVIVAL

6.1 INTRODUCTION

A number of factors must be considered in seeking to ensure that, having safely abandoned a unit, people are to survive until they are brought to safety. These may be included under the headings of:

Physiological : These concern physical well being.

Environmental : These concern external conditions having a direct bearing upon the foregoing.

Human : The ability of the body to react in the best way to combat the conditions.

Rescue Factors : How quickly can they be located and when they are located how will they be brought to safety.

These factors must now been examined in order to be able to determine criteria to be applied to any system designed to enable them to survive.

6.2 PHYSIOLOGICAL

6.2.1 Drowning

Most deaths in the sea have occurred from drowning. The reason is inability to avoid inhaling water, normally through lack of buoyancy, waves breaking over the face or incapacitation due to cold. The last factor is very common in areas where the sea temperature is well below mean body temperature[1].

If a man in the water is to avoid drowning for longer than brief periods, even in temperate, calm water and in a conscious condition, he must be provided with

buoyancy to keep him afloat with his face well clear of the water.

In rough seas the need to keep his face clear of the water and to avoid him inhaling waves or spray is also fundamental, though more difficult to achieve. Men dressed in survival suits and wearing life jackets have perished in rough seas because their life-saving equipment has not achieved this requirement.[3]

If men are unconscious, the need to prevent them inhaling water is as acute as ever but even more difficult to achieve as they are incapable of regulating their breathing to assist. It is therefore necessary to ensure that their faces do not become immersed in water or spray.

To achieve these requirements, it is necessary to ensure that, under all conditions, survivors float on their backs, with their heads held up and with some suitable form of shield to protect their airways from water and spray when they are in heavy seas.

The means of achieving this objective should not rely on manual intervention by survivors as they may well be unconscious, confused or for other reasons incapable of taking the right action. The exception to this is in helicopters where the bulk of an inflated life jacket or a non-inflatable life jacket which fulfills the needs set out above may prevent exit through escape doors. Only manually inflatable jackets should therefore be worn in helicopters.

6.2.2 Hypothermia

This is a subject about which a great deal has been learnt since the last war when scores of mariners succumbed to the sea because their body temperature was

lowered beyond a critical level before they were rescued, or before they had an opportunity of rescuing themselves. Hypothermia often leads to drowning through incapacitation which results in an inability to make the effort to keep one's head out of water or spray. It is undoubtedly the greatest enemy in cold water areas because it leads either to death in its own right or to drowning through incapacitation.

37°C is taken as the normal body core temperature. If this falls 2 C° to 35°C a man will begin to become incapacitated. He will become confused and disorientated. This state will become progressively worse as his temperature drops further, until at 33°C he will be semi-conscious. Shivering will be replaced by muscle rigidity. At 30°C he will lose consciousness and at 28°C ventricular fibrillation will occur. He may well not recover beyond this point (see Figure 3 in paragraph 4.3.2)[2].

Any man immersed in water will eventually die of hypothermia, no matter how well he is protected, but the time taken for him to die would depend on the following:[3]

- Water temperature
- Turbulence of the water
- Wind speed

It would also depend to some degree upon the following personal factors:

- His mass to surface area ratio
- The amount of sub-cutaneous fat
- His physical fitness
- His general mental state

Considering water of about 5°C, if a man wearing ordinary clothes were to be immersed in it his body core temperature would drop by about 2 C° for each hour immersed. If he was wearing a leaky immersion suit this drop in core temperature would be reduced to about 1 C° per hour immersed. If he was wearing a sound water-tight survival suit the drop in core temperature would be reduced to about 0.5 C° per hour immersed. These figures are approximate but would apply for the first few hours only with any reliability. Beyond that point little is known[3&4].

To reduce the water temperature to -1.8°C would make little difference compared with the difference brought about by the personal factors mentioned above in view of the very big differential in the first instance between 37°C (normal core temperature) and 5°C or -1.8°C (water temperature).

Since a man immersed in very cold water will lose body heat no matter how well he is protected, it is necessary to decide upon how long he could reasonably be expected to be in the water before being picked up, and then match personal immersion protection with this period. It must also be borne in mind that a man can also become hypothermic in a dry environment if it is sufficiently cold. Therefore all people must be thermally protected when exposed to low temperatures.

It can be assumed that there are two alternatives for recovering people from the water in an area where there are no fixed platforms and therefore no facilities for an offshore based helicopter. These alternatives are either shore based winch-equipped helicopters with trained winchmen and crew, or rescue boat equipped rescue vessels with appropriately trained crews.

In a busy offshore area without fixed platforms it may be that floating facilities for a helicopter base may be feasible but for the purpose of this study the chances of this happening are discounted.

Turning first to helicopters, it should take a maximum of one hour to fit a winch and be airborne, provided there is always a duty crew on standby (British Airways Helicopters on SAR contract in North Sea averaged fifteen minutes)[5]. Assuming that all offshore units are served by helicopters, it may take a maximum of three hours to fly to the area and rescue a full complement of survivors though it would hopefully take less. Therefore survivors rescued by helicopter should be rescued within four hours.

If a survivor is to be rescued by boat or rescue ship, the means available will probably limit the rate of recovery of people from the water to about one every four to five minutes per pick-up boat. This estimate is based upon allowances for location, approach and recovery of individual survivors by pick-up boats, supplemented by recovery of survivors direct to rescue ships. It also takes account of initial reaction time. Clearly it can only represent a rough estimate on which to base assumptions but, as such, indicates that to rescue fifty survivors would take of the order of four hours with one pick-up boat and several trained crews. This could be improved upon in direct proportion to pick-up boats available. It is to be hoped that fewer people than this would be in the sea as the intention would be to abandon units by helicopter or lifeboat but precedent suggests that such numbers should not be discounted.

These two rough estimates indicate that an objective of ensuring that survivors are kept alive in the sea for

at least four hours should be made.

As noted above if a man's core temperature drops from normal of 37°C to 35°C he will begin to become incapacitated. It is therefore recommended that the objective of thermal protective clothing should be to keep his core temperature above 35°C after four hours in -1.8°C water, that is not let it fall by more than 2C° in that time. This is in an ideal situation assuming that the means of protection is at hand, the man has time to put it on and it fits.

It is further recommended that a second line of protection should be of a 'throw away' type which could be stored at convenient points over the rig for personnel who could not don primary thermal protection clothing, and which would keep a wearer's core temperature above 33°C over a period of four hours. This would mean that although he would not be in as good a condition as the man wearing the primary type of protection, his chances of survival are still reasonable.

It cannot be stressed too strongly that, no matter what protection men in the water have, the longer they remain in the water, the less likely will be their survival. Therefore every effort should be made to recover people from the water as quickly as possible.

6.2.3 Cold Shock

Sudden immersion of the body in very cold water induces a condition known as 'cold shock'. This sudden shock may cause ventricular fibrillation and/or uncontrolled breathing (that is extremely rapid gasps and consequent hyperventilation). This can result in death from drowning. The condition can be avoided if the body is

introduced to the extreme cold more slowly and preferably kept dry. Accordingly, thermal protection for persons likely to enter very cold water should be designed to keep the body dry or at least slow the ingress of cold water to less than five litres per hour[3].

6.2.4 Freezing Cold Injuries

The freezing point of tissue fluid is about -0.55°C. The freezing point of skin is about -0.53°C. Permanent cold injuries as a result of freezing (frost bite) will occur if extremities (or any skin area) are left exposed and subjected to immersion in water below these temperatures for more than a very short time, say a few minutes[3].

6.2.5 Non-Freezing Cold Injuries

If extremities are immersed for long periods in water, even if it is well above the freezing point of skin, say as high as 15°C, non-freezing cold injuries can occur. Affected limbs will suffer pain and discomfort by relatively minor changes of temperature thereafter. There is no known cure. This condition was known as 'Trench foot' in the 1914/18 war and there were occurrences of it again amongst servicemen serving in the Falklands campaign in 1982[3].

6.2.6 Cold Incapacitation

If extremities, particularly hands, are immersed unprotected in water of 5°C or below, the fingers will become unusable in as little as three or four minutes. The rapidity with which this occurs becomes less with higher water temperatures up to about 20°C when the effect will not be noticed[3].

6.2.7 Nutrition

The requirements for nutrition of survivors are well covered by IMO guidance on life saving in Chapter III of the 'International Conference on the Safety of Life at Sea'. For individual people in the sea off Eastern Canada, protected only by survival suits and who are not soon rescued (within four hours - see para 6.2.2), death is likely to occur for other reasons before lack of nutrition becomes a problem.

6.2.8 Air Breathed

Survivors must of course be able to breath normal fresh air irrespective of conditions around them. If abandonment has resulted from a blow-out, with consequent release of gas, the environment could conceivably be polluted, though it is highly probable that wind or fire would disperse the gas. Only the hydrogen sulphide content of most hydrocarbon gases is toxic though the gases themselves, if concentrated, can cause suffocation.

6.2.9 Sea Sickness

Sea sickness or motion sickness can be encountered even if one is floating freely, that is not in a boat or other vessel. It can also of course be encountered quite badly in a lifeboat, survival capsule or inflatable raft.

Apart from being very demoralising, sea sickness is very weakening since it not only results in loss of valuable nutrition which is needed to both maintain body temperature and give energy when the time for rescue comes, but it also loses valuable body fluid

(see also section 6.2.11). There is also the danger that the floating survivor, especially if incapacitated through cold, may inhale the vomitus and die from that cause[3].

6.2.10 Burns

If the reason for abandonment is a blow-out it may well be that the sea surface is covered for some distance round the rig with oil which may be burning. Survival systems may therefore have to transit this area in the initial stages of survival though, in fact, this is in many cases unlikely as the area of the oil slick will tend to be down wind and/or tide of the rig. Nonetheless the possibility cannot be discounted and the same protection is therefore required as is needed for abandonment.

6.2.11 Body Fluid Loss

Fluid loss as a result of immersion in very cold water can be as great as one and a half or even two litres because of over-stimulation of the kidneys and consequent urination. This fluid loss is important because it means in effect that the volume of blood is reduced. If a man is quickly lifted from the water, in a vertical position, with a reduced volume of blood there may be insufficient circulating fluid to fill his vascular system. The upper part of his body - including his heart - will be starved of blood and ventricular fibrillation will occur. This will probably result in death. This has happened on a number of occasions; men who were conscious and appeared well have been winched up to a helicopter and been found to be dead on arrival[3].

6.3 ENVIRONMENTAL

The environment in which survivors exist clearly plays an important part in their continued survival. In other paragraphs in this Section, the effect of the environment on the various factors affecting survival is discussed. The purpose of this paragraph is to set out the environmental conditions which must be catered for by survival systems.

For the same reasons as were outlined in paragraph 4.2 above, typical severe storm conditions are used to provide criteria for survival.

Details of such environmental conditions in 14 areas off the east coast of Canada are contained in Appendix A. For ease of reference, the 14 areas are also shown in Figure 2 in paragraph 4.2.1.

Some of the factors which most affect survival are sea surface temperature, air temperature, wind speed, wave height and visibility. 'Blocks' of similar typical severe storm conditions linked geographically and seasonally are shown in Table 4 below.

In broad terms, typical severe storm conditions vary between the following limits, area by area:

- Max wind speed : 50 - 70 knots
- Max wave height : 6 - 17 metres
- Min Air temp : -20° - +11°C
- Min Sea temp : -1.8°C - +5°C
- Visibility : Less than ½ mile or cloud ceiling less than 300 feet 10%-45% of the time.

Another factor which can affect the recovery of survivors

from life saving craft is the duration of gales or storms. These are summarised in Table 5 below. Gales are winds from 34 to 47 knots, significant wave height 9 metres; and storms are winds and wave heights above these figures.

BLOCK	TYPICAL SEVERE STORM CONDITIONS	SEASONS/AREAS
A	Max wind 50-60 kts Max wave height 6-10m Min air temp -2° - +5°C Sea temp-1.8° - +6°C Ceiling 300' vis ½ mile for under 30%	Spring 9-14 Summer 1-4
B	Max wind 50-60kts Max wave height 6-10m Min air temp +1° - +11°C Sea temp +2° - +14°C Ceiling 300' vis ½ mile 15-45%	Summer 5-14 Autumn 9-14
C	Max wind 50-65 kts Max wave height 14m Min air temp +1° - +2°c Sea temp +5° - +10°C Ceiling 300' vis ½ mile 25-30%	Spring 6,7,8 Autumn 6,7,8
D	Max wind 60-70kts Max wave height 12-17m Min air temp -8°C - -4°C Sea temp -1.8° - +4°C Ceiling 300' vis ½ 20-30%	Winter 6,7,8, 9,12,13
E	Max wind 55-70kts Max wave height 7-9m Min air temp -7° - -20°C Sea temp -1.8° - +4°C Ceiling 300' vis ½ mile 15-30%	Winter 9,10, 11,12,14

Table 4 ENVIRONMENTAL 'BLOCKS' - SURVIVAL[6]

AREAS	TYPICAL STORM DURATION (HOURS)	TYPICAL GALE DURATION (HOURS)	SEASON
6,7,8 9,12 10,11,13,14	12 - 15 8 - 12 6 - 9	24 - 36 30 - 36 18 - 24	Spring
1,2 3,4,6,7,8 5,9,12,13, 14 10,11	6 6 6 4 - 6	24 - 30 24 12 - 18 12 - 18	Summer
3,4 5,10,11,13, 14 6,7,8 9,12	6 - 8 6 - 9 12 - 15 9 - 12	24 - 30 18 - 24 24 - 36 18 - 24	Autumn
6,7,8 9,12 10,11 13,14	24 10 - 15 9 - 12 12	48 30 - 36 24 - 30 36	Winter

Table 5 TYPICAL GALE AND STORM DURATION [6]

In more general terms, in typical severe storms, gale force winds can last for between 12 and 48 hours and storm force winds 4 and 24 hours, depending on the area in which they occur. Naturally, seas remain rough for longer periods.

Ice, in at least one of its various forms, affects all areas at some time during the year. It will be noted that no details are given in the table 6 for areas 1 - 5 in spring and winter and 1 - 2 in autumn. This is because of ice cover being such as to prevent drilling using conventional MODUs. Sea ice is possible beyond these periods and areas. In addition, ice bergs can affect survival and icing over of survival craft can be expected at some stages of the year and must therefore be considered a factor in survival. Ice conditions are summarised in Table 6 below.

'Variable' icing indicates variations from light in gales to very severe in storms. The table shows that, in general terms, icing can be expected during severe storms in all areas in winter and in some areas at other seasons. Ice bergs are possible and sea ice can be expected at some seasons of the year in all areas except 13 and 14.

AREAS	ICING	ICE BERGS	SEA ICE	SEASON
6,7,8 9,12 10,11	Occasional Likely -	Likely - Likely	Possible Light -	Spring
1,2 3,4 5 6-12	Light - - -	Yes Yes Yes Poss/likely	Yes Likely Possible -	Summer
3,4 5 10	Occ light - -	Yes Possible Possible	Yes(late) -	Autumn
6,7,8 9 10,11 12 13,14	Variable Variable Variable Variable Variable	Possible Possible Possible - -	Possible Possible Likely Possible -	Winter

Table 6 ICE OCCURRENCE [6]

Note: Severe sea ice cover affects Areas 1 and 2 in Spring, Autumn and Winter and in Areas 3, 4 and 5 in Spring and Winter.

6.4 HUMAN

6.4.1 Ergonomics

Ergonomics is 'the study of the mental and physical capacities of persons in relation to demands made upon them by various kinds of work' (as defined in the 1976 edition of Longman's Modern English Dictionary).

It has frequently been demonstrated that a man's mental state is very important if he is to survive. He must <u>want</u> to survive and must be reasonably confident that survival is possible. This mental state is very much tied up with his physical state. The mental and physical capacity of a man in a sound lifeboat would be much greater than a man in a sound survival suit floating in a good posture in the sea. They would probably both be seasick and cold but the man in the survival suit would probably give up the struggle to live much more quickly than the man in the lifeboat.

Conversely a man in a survival system who is probably very frightened and also probably very cold must not be given tasks to carry out beyond his mental and physical capabilities <u>in that state</u>. Thinking must be reduced to a minimum and jobs must take into account cold fingers which are 'all thumbs'. Great dexterity will not be possible.

6.4.2 <u>Training</u>

It is absolutely no use giving a man first class survival equipment if he is not trained in its use. In the Alexander L Kielland disaster only eight persons put on survival suits. Of these four died and four survived. Of the four who survived three wore suits not properly zipped up[7]. A man who has been taught the principle of a survival suit will zip it up, even though it has water in it, to prevent circulation of the water. Men must be taught not only how to operate their equipment during abandonment but also during the survival phase. They must be taught how to survive including the basic principles of survival.

6.4.3 <u>Communications</u>

Communications between survivors play an important part in the chances of ultimate rescue. Communications with rescuers are discussed in the following paragraph.

The most important purpose of communications between survivors is to ensure that they try and remain closely bunched so that, when rescue comes, delays will not occur due to the distance between them. This applies to individual survivors and to survivors in survival craft. Means must be available for individual survivors to attach themselves one to the next, though precautions must be taken to avoid the lighter survivors being dragged through breaking waves unnecessarily by their heavier fellow survivors. Means must also be available for survivors in different survival craft to remain in contact with one another and so co-ordinate their actions. These can be the same communications arrangements as are used for communications with SAR forces.

These arrangements will, in addition to aiding rescue, help to maintain morale amongst survivors.

6.5 RESCUE

6.5.1 Communications

In any rescue operation it is necessary for many reasons not only for the survivors to be able to speak to their rescuers and vice versa but also for the rescuers to be able to talk to each other. It was only after much discussion between international parties and the authorities in the North Sea area that approval was given for offshore rescue vessels to carry an aeronautical VHF frequency. This has now come about - there is no abuse and ships and helicopters can now work together properly instead of attempting to make visual signals. Coordination of effort by a central controller is vitally important. It is also important from points of view not only of locating survivors but also in establishing priorities, that a dialogue between

rescued and rescuer can be carried out. For example, if a lifeboat has in it a badly injured man not only would it be important to concentrate on rescuing that lifeboat but it would be necessary to give the others in the boat medical advice.

Another point of course is that there is nothing like other human contact in these circumstances to improve morale. It has frequently been commented that many people who have survived until help is evidently at hand have then apparently reduced their efforts to live and so perished before final rescue. The chances of this happening can be reduced if good communication is possible between survivors and rescuers.

6.5.2 Location

Particularly in a cold water area, where there is a definite limit on survival time in the water irrespective of protection, it is important to rescue survivors as quickly as possible. It must be possible to locate them quickly in any climatic conditions which may be encountered. It is interesting to note that during the Ocean Ranger disaster, helicopter pilots stated that at night the small lights fitted to the lifejackets were easy to see in the water but with the onset of daylight this became more difficult. With full daylight and the sea conditions prevailing at the time it was almost impossible to see the lifejackets[8].

A ship master stated that the fluorescent tape which was attached to the lifejackets was highly visible at night when illuminated by a searchlight[8].

Means of locating individuals and groups of survivors in the water from rescue vessels are essential. They must be capable of assisting location in daylight and darkness, in heavy spray, waves of up to 17 metres or fog.

6.5.3 Transfer

Having got to the point where help is at hand it is important to ensure that the actual transfer to safety, be it from the water or from a life saving appliance, is as hazard free as possible. It must also be borne in mind that a survivor may already be injured. Death as a result of lifting from the water must be avoided (see 6.2.10). The transfer of men from lifeboats must not end in death or even serious injury.

The means of transfer will depend largely upon on the capabilities of the rescue vessel. However, survival systems must be compatible with the transfer means which may be used. In particular aids for recovering individual survivors from the water should be built into their survival suits.

It is most unlikely that transfer from rigid survival craft or inflatable liferafts will be possible in gale or storm conditions. Such conditions may last for up to 48 hours (see paragraph 6.3). Means should therefore be available to safeguard survivors in such craft for at least that period.

A means of passing a tow without hazarding the survival craft or those inside it is an important step in this direction.

Section 6 - References

1. Hypothermia, Exposure, Rescue and Treatment - Sarg.Cdr. F St C Golden. Safety and Health in the Oil and Gas Extractive Industries Symposium, 1983.

2. 'Recognition and Treatment of Immersion Hypothermia' - Sarg.Cdr. F St C Golden. Proceedings of the Royal Society of Medicine, October 1973, Vol 66 NO 10 pp 10/58 - 10/61 (United Services Section pp 16-19).

3. Discussions with Surg Cdr F St C Golden, Royal Navy.

4. Data obtained from DCIEM, Downsview, Ontario.

5. Discussions with senior representatives of British Airways Helicopters Limited.

6. Information provided by Nordco Limited.

7. 'The Emergency Management of the Alexander L Kielland' - Sivert Øveraas. International Conference on Emergency Management Offshore - 1981.

8. US National Transportation Safety Board Draft Marine Accident Report ' Capsizing and Sinking of the US Mobile Offshore Drilling Unit Ocean Ranger Off The East Coast of Canada 166 Nautical Miles East of St Johns, Newfoundland, 15 February 1982'.

7. CRITERIA FOR SURVIVAL SYSTEMS

7.1 INTRODUCTION

Criteria for survival systems must take account of all the factors affecting survival discussed in Section 6. These criteria can then be used, in conjunction with the criteria for abandonment systems, as a yardstick against which existing systems may be measured and to which future systems can be designed.

It must be borne in mind that all criteria must be applied to all cases, though in some instances the problem will be greater than in others. For example, a man can become hypothermic in a lifeboat if it is cold enough and therefore he must be protected as well as the man in the water.

7.2 PHYSIOLOGICAL

7.2.1 Drowning

Systems must prevent survivors inhaling water or spray under conditions of wind speeds up to 70 knots and wave heights to a maximum of 17 metres and including the situation where the survivor is unconscious.

7.2.2 Hypothermia

For the purpose of this paragraph a fitted survival suit is defined as a primary survival system. Primary systems must be capable of maintaining survivors' core temperatures at 35°C or greater for a period of at least four hours when the survivor is immersed in sea water at -1.8°C or for periods of at least four days in survival craft. Second line survival suits should be capable of maintaining survivors' core temperatures at 33°C or greater for a period of at least four hours when the survivor is immersed in sea water at -1.8°C.

7.2.3 Cold Shock

Large areas of skin must be prevented from rapid contact with cold water. Ingress of water into any form of body protection should be avoided and in any event must not be at a rate greater than five litres per hour.

7.2.4 Freezing Cold Injuries (frost bite)

In order to avoid this condition extremities should be prevented from dropping below -0.55°C even for short periods.

7.2.5 Non-Freezing Cold Injuries (trench foot)

In order to avoid this condition the surface of extremities should not be allowed to drop below 15°C for periods greater than four hours.

7.2.6 Cold Incapacitation of Extremities

Provided the criterion in 7.2.5 above is met this will not be a problem.

7.2.7 Air Breathed

Any survival system should ensure the supply of respirable air sufficient for all men carried for a period of at least four days. This should take account of a need to transit areas of gas or burning oil when close to the abandoned platform which may take up to half an hour.

?

7.2.8 Sea Sickness

Supplies of anti-sea sick drugs should be readily available on all systems which involve floating on the

water. This should apply to one man systems, ie survival suits. Means should be available to take the drugs without exposure of body or limbs to the elements.

7.2.9 Burns

Any system should be able to afford protection to survivors against fire in the event of having to pass through burning oil on the sea surface in order to reach safety.

7.2.10 Body Fluid

Supplies of Lysine Asopressin or similar drugs to reduce stimulation of the kidneys should be provided with survival systems, particularly survival suits. Means should be available to take the drug without exposure of body or limbs to the elements.

7.3 HUMAN

7.3.1 Ergonomic

All survival systems must be simple to operate. Simple, clear instructions should be posted. No great dexterity must be necessary. Operation should be by hand rather than finger.

7.3.2 Training

This is one of the most important aspects of survival. Theoretical training must include an explanation of the physiology of cold water survival and a description of its application. Practical training must be given in the operation of systems. The person in charge of each survival unit should have received practical training in its operation on site.

7.3.3 Communications

Means should be available to ensure that individual survivors can be retained close to each other and that survivors in survival craft can communicate with each other.

7.4 RESCUE

7.4.1 Communications

All survival systems except individual survival suits must have the capability of voice communication with any would-be rescuers on appropriate marine and aero-nautical frequencies.

7.4.2 Location

All life saving appliances, be they designed for one person or several, should be equipped with the following:

1. Visible means of detection at night not relying on another source of light.

2. Highly reflective material to assist in night detection.

3. An audible signal to assist location in fog. This may be a fog signal in the case of a boat or capsule, or a whistle in the case of a man.

4. A radio beacon, possibly using satellite communications. In the case of survivors in the water this can be in the nature of one floating beacon per group. A radar transponder should be considered for large unit systems, or for groups in the water a buoy mounted unit could be deployed.

7.4.3 Transfer

All survival systems either must be capable of safely transferring survivors to rescue craft in a seaway without endangering the rest of the system or those in it, or they must be capable of being towed without hazarding the survival craft or those inside it. All systems which can carry stretcher cases should have a means of transferring them.

All winching apparatus should be designed to lift a man either horizontally or in the foetal position. This latter is easily achieved by passing a second lifting strop behind the knees of a survivor. Survival suits should be designed to incorporate such a system.

8. ASSESSMENT OF ABANDONMENT/SURVIVAL SYSTEMS

In this section the various existing or planned systems are described and compared with the criteria in sections 5 and 7. When there are shortcomings these are highlighted and where possible, suggestions are made for overcoming these shortcomings.- Where inability to provide satisfactory means for abandonment or survival results from environmental factors, the frequency of occurrence of the conditions offshore Eastern Canada exceeding those which would allow success are examined.

The conclusions are summarised in Tables 7 and 8 in Section 9.

8.1 EVACUATION BY HELICOPTER*

8.1.1 Helicopter landing on

This means of abandonment may only be used on units having either a helicopter deck or a large flat space with sufficient strength to accept a helicopter. This restricts units under consideration to those used for drilling, ie MODUs.

Evacuation by helicopter is normally the primary means of evacuation for offshore units. Only if this means is unavailable would abandonment by other means be attempted. Its greatest limitation, as will be seen below, is the response time required. In section 6.2.2, the response times of helicopters in recovering survivors were examined. The factors examined in that context are equally applicable in this. It was concluded that helicopters could be available at the site of the rescue within four hours.

* Note: The facts quoted in this section have, where other references are not given, been obtained in discussions with senior representatives of British Airways Helicopters Limited.

The ability of helicopters to undertake rescue naturally depends upon their own characteristics. Range, speed and capacity are probably the most important.

The first and last of these are currently best provided in the Chinook helicopter and, in the more remote areas of Eastern Canadian waters, this may be the only machine capable of operating suitable evacuation facilities.

The capabilities of helicopters to undertake evacuation against the criteria set out in sections 5 and 7 are examined below.

In an emergency, pitch and roll of 7° or 8° can be tolerated by conventional single main rotor helicopters, although normal operating limits are 3° to 4°. The Chinook is unusual in that, having two main rotors which overlap, the roll is officially limited to 3° although it can operate safely at up to 6° in emergencies. Pitch, however, is only limited to 15° for normal operations but can go up to 20° in an emergency.

There is no set limit to the deck angle at which helicopters can transfer people. Under ideal conditions, it is possible that 40° would be achievable using an accepted technique of resting one or more wheels against the deck while maintaining some control with rotors. However this could by no means be guaranteed. If this is not possible, winching may be carried out but this reduces the rate of transfer. See 8.1.2 below.

The height of the deck from which survivors are being evacuated is not important.

Helicopters operate independently of any external power supplies.

Obstructions to helicopters landing can arise in times of emergency. However, this should not normally occur. If it does, winching (see 8.1.2 below) may be possible.

The numbers which can be evacuated from offshore installations depend upon the capacities of helicopters and the numbers of helicopters available. The emergency capacities of helicopters normally used offshore are as follows, though they may have to be reduced for long flights:

Bell 212 - 18
Super Puma - 24
S61 - 44
Chinook - 80+

It is therefore possible that a single Chinook or two S61s could evacuate all the personnel from one MODU, though this would naturally depend on many other factors.

Helicopters cannot respond within the time scales set in the criteria. It will be noted from section 3, however, that in some cases several hours may elapse from first indication of an emergency to final need for abandonment. In such cases there is no doubt that a helicopter evacuation is superior to anything else known at present. Survivors are kept dry and relatively warm. Stretcher cases can be carried in relative comfort and can be delivered directly to hospital.

If a problem occurs which seems likely to develop into a major emergency, the evacuation by helicopter of all those not immediately involved may be prudent. In this case the limitations in response time from which shore based helicopters suffer may not be material. If only one helicopter is available and it cannot accommodate

all those requiring evacuation, but there are other rigs in the area, it would be possible to ferry persons to those other rigs as a first step towards evacuation to shore. For this reason alone it is important to have refuelling facilities on all offshore installations.

So far as evacuees are concerned, evacuation by helicopter requires no special skills beyond those which they accept as a normal part of transfer between MODU and shore.

Helicopters are capable of operating satisfactorily within the criteria set for air temperatures if they are properly equipped.

The effect of wave height on helicopter operations is only manifest through pitch and roll, discussed above.

Maximum wind speed does not affect helicopter operations except in the time taken to transit against strong headwinds and in start up, though gusting can make operations difficult and sometimes hazardous. Start up for most helicopters is only possible to a wind speed of 50 knots. In the Chinook, although theoretically start up to 50 knots is allowed, in practice this is normally restricted to 35 knots. Start-up in the theoretically excessive conditions may be possible if a lee can be provided.

Visibility has a distinct effect on helicopter operations. Normal limits for rig let down are as follows:

a) Visual flight rating -

Day: cloud ceiling 250 feet, horizontal visibility 1,000 yards.

? Night: cloud ceiling 1,000 feet, horizontal visibility 6,500 yards or cloud ceiling 500 feet, horizontal visibility 10,000 yards.
(6mi.)

b) Instrument flight rating -

Cloud ceiling 250 feet, horizontal visibility 660 yards.

All these limits are subject to full serviceability. Equipment exists and is in use in military aircraft and commercial aircraft on SAR contract in the North Sea which allows helicopters to fly in conditions of virtually zero visibility. New developments in the use of infra red imaging systems provide for greatly enhanced capabilities over those available with visual flying or standard instruments. One such system, currently being developed, is the Redowl helmet display system which provides greatly enhanced vision linked to the actual direction in which the pilot is looking[1].

Helicopters cannot operate in conditions of fire.

Helicopters cannot operate in irrespirable or combustible gaseous environments.

The acceleration criteria are well met.

No special training for passengers beyond that normally given is required.

Helicopters would normally be fully equipped with suitable communication facilities.

No problems are likely with temperature, electric shock, extreme physical exertion, breathing systems, drowning, hypothermia, sea sickness, burns or body fluid.

8.1.2 Helicopter winching

This method of removing survivors from a wreck has the disadvantage of slowness when a great many survivors are involved and there is only one helicopter, though this is reduced if such devices as the EMPRA or Bennex nets are used. It is however a very good way of removing survivors from a supply ship or ditched helicopter when relatively small numbers are involved.

A well trained helicopter crew including a winchman will winch about one man in three minutes if conditions are straightforward or one man in five minutes in difficult conditions. The type of winch selected is important. Several types are available driven by air, electricity or hydraulics.

In all other respects, the manner in which helicopter winching meets the criteria set out in sections 5 and 7 is the same as that for helicopters landing on.

8.2 DRY TRANSFER

Dry transfer systems, as the name implies, are systems whereby offshore installations can be abandoned without survivors entering the sea. In the context considered here, the use of helicopters is not included as that has already been assessed.

Several different systems have been designed, although many of them only to the conceptual stage. Some have been developed to prototype stage. None have so far been fitted commercially to offshore installations.

There are two main types of dry evacuation system currently under consideration.

The first system is based on the idea of a rigid bridge which can be passed from an installation to a rescue vessel. This is a concept which appears more attractive for fixed installations than MODUs in view of its size and weight and the probable need to have a large vessel to receive evacuees.

The second approach is based on 'replenishment at sea' systems used by many navies. Two such systems provide examples. It is understood that one proposed by Hebburn in Canada has the advantage of simplicity and uses a wire in constant tension connecting the MODU to the rescue vessel. However its performance is appreciably limited by sea state.

The second such system has been developed in the United Kingdom by GEC (see Fig 4). It also employs a wire in tension but this wire is rigged in the form of a loop which combines suspension of the load in the lower line with outhaul and inhaul by the upper part. There is a further line (taut wire) above this loop which measures the relative positions of the two units. This information is then transmitted back to a computer in the receiving vessel and is used to adjust the tension in such a way that the build up of resonant frequencies in the lines will be prevented. If this is not done it has been found that severe oscillation can occur, sometimes with disastrous results. This refinement enables the system to operate at lower tensions than would otherwise be possible.

The main items of equipment at the MODU end are a docking platform and receiving arm, both of which are mounted on a vertical steel column which itself is mounted in plain bearings, allowing it to swing in a 150° horizontal arc. This allows the whole assembly to line up with the rescue vessel and thus, as long as the rescue vessel keeps station within the 150° arc, the system can operate satisfactorily. Tank tests indicate that the most satisfactory positioning for the system is about 40° off the weather. To achieve maximum flexibility it is therefore necessary that one

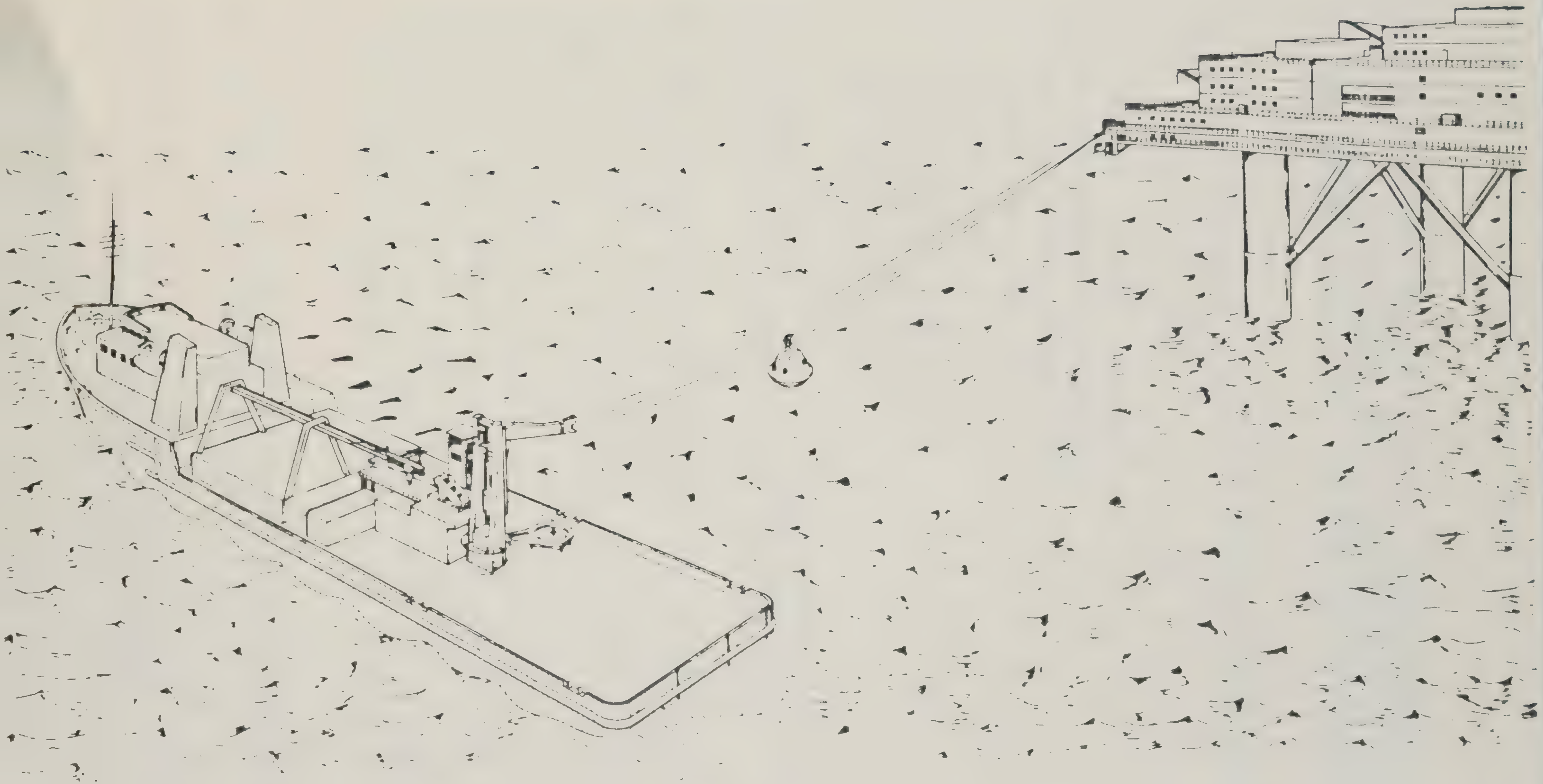


FIG. 4 GEC DRY TRANSFER SYSTEM.

terminal is mounted on each corner of a MODU, making a total of four for a rectangular unit. Above each platform is a pedestal mounted pneumatic line-throwing gun for passing the first line.

The rescue vessel carries the major part of the equipment needed which consists of:

- a gearbox and winch assembly
- two 250 horsepower power packs
- tank containing hydraulic oil
- tension measuring unit
- kingpost and arm
- 100 horsepower power pack
- capsule handling frame
- two escape capsules.

The escape capsules on the original design are modified Whittaker capsules capable of carrying 18 men each.

The MODU mounted equipment does not take up a great deal of space and weighs less than 3 imperial tons. The rescue ship equipment takes up more space and has a weight of about 57 imperial tons. A prototype of this system has been ordered for use aboard a new fixed production platform in the Norwegian sector. We believe it is more suitable for fixed structures than MODUs in view of the cost and the need for a dedicated rescue ship to be available. However, it provides a possible option and is therefore examined as an example of a dry transfer system against the criteria in sections 5 and 7.

If the MODU has a 40° list the terminals at the high side of the unit should be capable of operation.

A height above water level of 35 metres presents no problem and indeed is some advantage over lesser heights.

All power supplies are built into the receiving ship except the pneumatic power for the line gun. This would be stored in an accumulator.

It is not envisaged that any obstruction could occur which would jeopardise the system's operation.

All on board, including stretcher cases, could be safely taken from the MODU.

The maximum distance between a MODU and rescue vessel is 225 feet. Total time taken to set up the equipment is about 25 minutes and time taken for one capsule cycle is about four and a quarter minutes. Thus, if no more than ninety men were on the MODU and assuming a capsule capacity of eighteen men, all could be evacuated in five trips taking a total of 21½ (say 22) minutes. Accordingly total evacuation including preparation would take at least three quarters of an hour from the time when the rescue vessel was in position. This would, of course, add a further period to the preparation and accordingly it is likely that about one hour should be set aside for complete evacuation. Although this exceeds the criteria, it is none the less possible that it would provide a satisfactory response time on many occasions.

All exposed parts of the system are very simple and thus require little maintenance. However, the electronics in the rescue vessel are very sophisticated although much of the research funds in developing this system were absorbed in producing a very reliable automatic fault finding system. The system is simple for evacuees to use.

This system is likely to be satisfactory for use in low air temperatures and icing, although some modifications may be necessary.

Tank tests with a simulated fixed platform and Ulstein 705 supply vessel acting as rescue vessel indicated safe

operation up to at least sea state 8 (ie maximum wave height up to 29 metres). This falls within the criterion for wave height although the criterion for wind speed may be marginal.

Operation in zero visibility would not be possible because of the necessity for those firing the line to see the ship. It is likely that the minimum visibility under which the system could be operated would be approximately 100 feet, representing the minimum safe distance to which a vessel could approach blind.

The system could not be operated if the rescue vessel needed to be positioned in an area of burning oil. Terminals could be designed to have protection against radiant heat. Use in an irrespirable or combustible gaseous environment would not be possible. Since it is envisaged that four abandonment points would be available, this should not matter.

Accelerations would be within those set out in the criteria.

Suitable communications could be provided.

Rapid temperature changes would be avoided. Environmental temperature would be retained within that set out in the criterion.

No problems from electrical shock are envisaged.

No extreme physical exertion would be required.

No respiratory problems are envisaged.

No problems are envisaged from drowning, hypothermia, cold shock, freezing cold injuries, non-freezing cold injuries, cold incapacitation of extremities, sea sickness, burns or body fluid loss.

Location and transfer of survivors would be automatically achieved by the system.

8.3 RIGID SURVIVAL CRAFT

These craft derive from traditional ship's lifeboats though in recent years those fitted in MODUs (Totally Enclosed Motor Propelled Survival Craft - TEMPSC) have grown further and further away from their predecessors.

Two main types of TEMPSC predominate in current use. One has a boat shaped hull and is launched from twin falls with off-load disengaging gear. The other has a more disc shaped hull and is launched from a single fall with on-load disengaging gear. A further type, currently only fitted to one MODU, is the Free Fall Lifeboat (FFL) which is dropped without falls into the sea.

Designs and a prototype exist for a 'Lifescape' which is based on the principle of a lifeboat but is designed to provide a safe haven onboard the parent unit which would only be launched in time of complete disaster. It is intended to be launched, when required, by a single fall with cantilever davit and free fall for the last 4 metres or so.

Conceptual designs exist for several types of underwater launched survival craft which are propelled from a position in the parent unit below the waterline and either surface clear of the unit, remain submerged for a set period before surfacing automatically or maintain a habitat for survivors on the sea bed in shallow areas, until rescue is available.

Designs exist for launching arrangements which would ensure that the TEMPSC is automatically pulled clear of the parent craft once in the water (PROD).

Some launch systems include guide-wires which steady the TEMPSC during launching and ensure that it is carried clear of the structure of the parent unit.

In supply ships, normal ships' lifeboats are sometimes fitted. Alternatively TEMPSC may be fitted. They are launched and recovered by normal ships' gravity davits.

Helicopters can not be equipped with rigid survival craft.

Because the permutations of launching arrangements and craft can be many, the extent to which the different types of launching systems and their craft meet the criteria established for abandonment and survival in Sections 5 and 7 above will be examined.

8.3.1 Twin Fall Gravity Davits

On MODUs, these davits either follow conventional ship design or, more often, utilise rigid davit outriggers anchored to the structure of the unit. Launching is controlled from inside the TEMPSC. No power supplies are required from the parent unit for launching as the craft are lowered by gravity with speed being controlled by a brake. Recovery after drill launching is achieved by the use of electric motors and winches.

Any height of launching point can be accommodated, though high winds affect the stability of TEMPSC being launched from such davits and the effect increases with increases of wind speed. Wind tunnel tests of scale models showed yaw oscillation to $\pm$ 45° with wind speeds over 50 knots and fall lengths of 17 metres and over. With the wind from right ahead of the TEMPSC, pendulous oscillation across the wind also occurred under several conditions[2].

Twin fall systems can operate satisfactorily with the parent unit listing providing they are mounted in such a way that the craft are lowered clear of structural members. However, in some cases this may not be possible. It is significant that it has been calculated

that a nearly empty TEMPSC can swing as much as 4.4 metres from the perpendicular during launch from davits at 20 metres deck height[3].

The effect of high seas can be to carry craft under the decks of column supported MODUs (semi-submersibles or jack-ups). They can also exert considerable slam forces on the hull of the TEMPSC at the moment of impact during launch. Lastly they can capsize a TEMPSC. Because no quantitative information is available concerning the maximum wave heights which can be tolerated by TEMPSC being launched by twin fall davits it is only possible to make some estimates based on associated information. It has been calculated that a TEMPSC could be carried sideways 12 metres in 0.9 seconds in 16.9 metre breaking waves; 1 second in 12.3 and 14.6 metre breaking waves; 1.2 seconds in 9.9 metre waves and 1.3 seconds in 8.1 metre waves[3]. Further calculations indicate that a boat can be set back up to 12 metres on release in wind force 7 and above[3]. It has also been calculated that a TEMPSC could be capsized if beam on to breaking seas of above 8.1 metres[3]. On this basis, seas of above about 8 metres could prove excessive for twin fall launched TEMPSC. Even with this limitation, a TEMPSC cannot be guaranteed to clear a structure safely unless it is lowered on a heading which, when it enters the water, ensures that it is propelled away from the structure. This in itself relies upon the means of propulsion being satisfactory which, by precedent, has not always been the case.

A recent study[3] found that of six TEMPSC launched in two incidents (Alexander L Kielland and Deep Sea Driller) one engine failed to start. However test drills indicate wide fluctuations in the reliability of engines in starting. One operator reported one or two failures in 1,500 starts during drills while another

reported frequent difficulty[3]. This evidence indicates that engines alone are not completely reliable and so may be insufficient to ensure that TEMPSC clear the structure on launching. This therefore encourages the use of some other means of ensuring that this is achieved - a means which normal twin fall systems do not provide.

Twin fall systems provide simple and quick operation with a limited number of preparatory steps required before they can be used. They therefore enable abandonment to be undertaken as soon as their TEMPSC have all necessary users onboard (minimum time for 44 men in 50 man craft two minutes - maximum ten minutes[3]).

The operation of twin fall davits is simple, with a limited number of potential failure modes. However precedents exist for some failures, in particular mechanical failures in the brake cable and brake operating mechanisms.

Twin fall davits can be operated successfully in gas and high radiant heat providing the users are able to enter the TEMPSC safely. However icing conditions can prevent their safe operation if special action is not taken to overcome this. Such action includes the heating of winch motors and brakes and the use of low temperature steels on all main structural members of the launching system. It is understood that such precautions have been prepared but have not yet been taken on MODUs.

8.3.2 <u>Single Fall Gravity Davits</u>

The chief advantage of single falls is that they provide only one place for disengagement and therefore reduce the chances of failures of disengagement. The chief disadvantage is that they allow greater movement,

and particularly rotation, of the TEMPSC while it is being lowered and hence can add to the difficulty of clearing the structure on release. A further disadvantage is that the single point of attachment must of course take the full load of the craft rather than half, which can result in bulky components.

In all other respects they operate with similar capabilities and limitations as twin fall systems.

8.3.3 Free Fall Launch

Free fall systems have been under development in Norway since 1973 although the idea seems to have originated in Spain in the early 1960s. Two main concepts have been developed: the skid concept and the vertical drop concept. After considerable research and development, production model free fall lifeboats have been fitted in five ships, one MODU (Dyvi Delta) and ordered for one North Sea production platform (Gullfaks A), although the latter is not yet built. The skid system has been used in ships and MODUs but the vertical drop system has been proved more suitable for the higher drops required for offshore platforms.

The skid system is designed to launch the TEMPSC at an angle of 35° from the horizontal though it can function satisfactorily, though with reduced forward speed of the TEMPSC on water entry, at angles between 15° and 50°. On MODUs, the skid assembly is designed to tilt to take account of variations in deck angle.

The free fall system, using the skid concept, is suitable in theory for launch from heights of up to 35 metres although some doubts have been expressed about its reliability above 25 metres. A recent paper[4] expresses the safe launching height in terms of H/L = 2.0 or, with well designed drop craft, H/L = 3.0, where

H = height of skid and L = length of craft. Thus, for a normal 60 man craft length (for craft used with this system) of 13 metres, drop heights of up to between 26 and 39 metres can be expected to be suitable. It should be noted that, while it has been claimed that the vertical drop system is suitable for heights up to 40 metres, the same source states that this formula is applicable to both systems. It is likely that the difference comes in the suitability of the design of the craft, as a major development in the vertical drop system was the complete redesign of the craft itself. Accordingly, it is reasonable to conclude that the limiting heights can be expressed as H/L = 2.0 for 'traditional' skid launch craft and H/L = 3.0 for vertical launch craft but that a skid system could be designed to launch a 'vertical launch' type craft.

No external sources of power supply are required to launch a craft by free fall. The system also provides means of launching craft on a single fall and allowing them to float off if the parent unit sinks. Neither of these systems requires external sources of power. To recover a craft after a drill launch, an electric motor, supplied from the unit's main supplies, is used to operate a winch.

The risk of a free fall system being hampered by obstructions depends upon the position in which the system is mounted relative to potential obstructions and the attitude of the parent unit. In normal circumstances, we believe it is unlikely that a free fall craft would strike the structure of the parent unit although a recent paper[2] referred to a need to drop a craft from a point substantially outboard from the structure to avoid collision during launch. It should be noted however that the free fall system being reported in this paper was fundamentally different from those currently in use.

One of the principal objectives of the free fall concept is to use the kinetic energy of the craft, built up during its fall, to carry it clear of the structure. This is achieved to the extent that in model tests, during the worst case, when landing against the bottom of the forward wave slope of a breaking wave, going through the first crest, diving into the next trough, traversing the second crest and finally being stopped by the third crest, the model travelled for about 11 seconds, clearing the drop point by about two boat lengths[5]. We can therefore assume that this system will ensure that craft clear the structure by at least this distance in wave heights up to those at which the model test was carried out, namely 9 metres.

The response time for free fall systems is very short. Embarkation into modern craft by 69 people can be achieved in 2½ minutes[5]. Preparation for launch involves tilting the launch ramp downwards in skid systems on MODUs, removing securing bolts and ensuring that all people onboard are properly strapped in.

Operation of the system is very simple and involves very few actions. Besides those involved with preparation, all that is required is for a hydraulic valve controlling the free fall lock to be operated and for the hydraulic pressure to be applied to release the lock by means of a handpump. The craft then slides down the skids and drops into the sea under gravity. If the craft is to be lowered on the single fall, this is attached and, in addition to releasing the free fall lock, the winch break is released from inside the craft and the craft is then lowered in the normal way. If float off is to be used, the preparation and operation is exactly the same as for free fall.

Protection against very cold air temperatures is only provided inside the TEMPSC. No currently available

special arrangements have been found to take account of icing which could well affect both the release mechanism and possibly the skid arrangements. However, such arrangements could probably be made without great difficulty.

The greatest wave height at which tests are recorded as having been carried out is 9 metres. It is claimed that, in theory, the craft can be launched safely into any wave height but, until evidence of the effectiveness of the system in waves of greater height is available, it is prudent to assume 9 metres to be the maximum wave height for safe use.

The comments about limitations of free fall systems imposed by wind which were made in a recent paper[2] were denied by the developers and manufacturers of free fall systems. It seems unlikely that wind has an appreciable effect on free fall systems.

The limitations on such systems imposed by fire are associated with the TEMPSC themselves and not with the launching system.

Great care has been exercised by those developing free fall systems to ensure that unacceptable accelerations are not imposed upon their occupants. Trials show that accelerations fall within the limits described in 4.3.4.

8.3.4 Combined Gravity/Free Fall Launch

This system is under development for some uses, in particular in the 'Lifescape'. It is in fact a development of a well established approach used in many warship applications, namely to lower boats to just above the crest of the waves and then drop them onto a crest.

In the 'Lifescape' system, the craft is suspended in a gravity release davit (see figure 5). The davit is controlled by a hydraulic winch. The davit carries the craft 10 to 12 metres clear of the parent structure. A thermistor sensor suspended in a crawfoot about 4 metres below the craft gives a positive signal when it is submerged in water. The operator can then stop the lowering of the craft and release it from inside for free fall. He is able to see out of the craft to simplify his judgement in this. The craft may therefore be dropped a maximum distance of 4 metres plus the wave height.

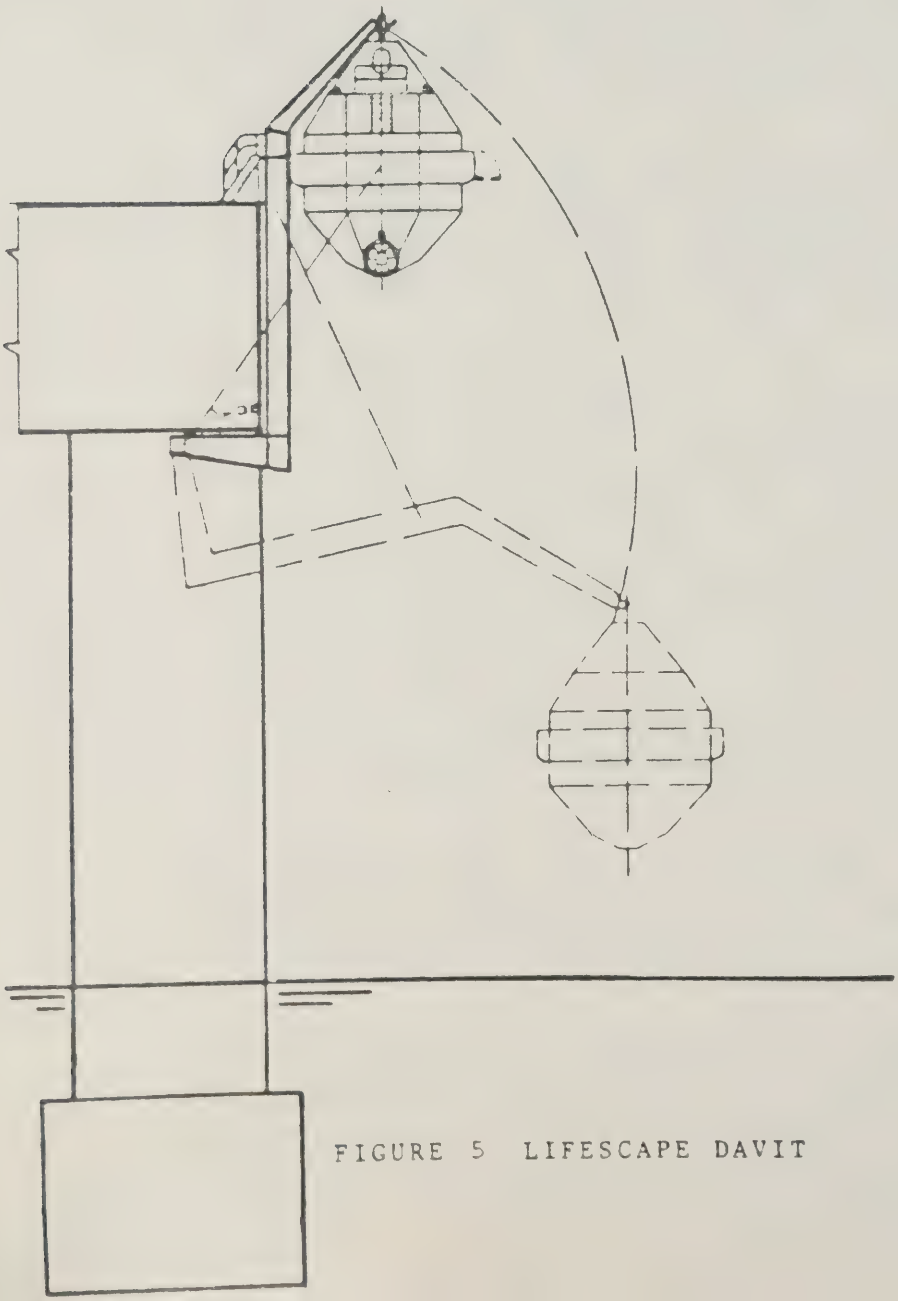


FIGURE 5 LIFESCAPE DAVIT

The system, as currently designed, is only capable of accommodating lists of up to 15° to 17½° in either direction. No information on the effect of trim angles has been obtained though it is unlikely that these will introduce limitations.

The system has been designed primarily for use in offshore applications and is therefore unlikely to suffer deck height limitations when used from MODUs.

No external sources of power are required for launch. The hydraulic pressure is maintained for the launch operation by means of an accumulator system. No external supply of electrical or pneumatic power is required.

The system is designed to launch the craft clear of obstructions. It is considered that the designed distance of 10 to 12 metres would barely be sufficient.

The design of the system provides for quick response times. No figures have been obtained to quantify them but it is likely that that the simplicity of the operation will ensure this. In addition, the concept of the 'Lifescape' envisages entry into the craft as soon as a major risk is recognised followed by launch only if essential. A Failure Modes and Effects Analysis of the current design gives very favourable results in terms of the design characteristics[6].

We believe that current designs would need to be modified in some respects to take account of very low air temperatures and icing conditions.

The maximum height from which the system is designed to be dropped and has so far been tested in the free fall condition is 15 metres. This sets a limit of 11 metres or in practice perhaps 12 metres on the acceptable wave height.

The rigid construction of the launch system makes it unlikely to be affected severely by high winds. The system is designed to be operated in fire and toxic gas environments. Accelerations associated with free fall are within the acceptable limits described in 4.3.4.

8.3.5 Submerged Launch

Submerged launch systems are still in the conceptual stage. Accordingly only the concept is addressed in assessing them against the criteria.

The purpose of launching survival craft from below the surface is principally to avoid the problems presented by entry to the water through the surface.

Deck angle of the parent unit of up to 40° could involve several design problems associated with the release of the survival craft from its normal mountings. They could no doubt be overcome but might involve added design complication.

Deck height is not applicable in this case but its equivalent, launch depth,is. In semi-submersibles the system must be designed to operate effectively whatever the draft of the unit. This can vary by as much as 15 metres.

It is entirely possible that the design could take account of the need to function without power supplies being available from the parent unit at the time of operation, though it is likely that they would be needed during normal conditions to ensure that hydraulic and pneumatic accumulators were kept fully charged.

The system should be designed in such a way that survival craft can be launched clear of obstructions.

The response time for such systems would depend in part on their design and in part on where they were mounted. In semi-submersibles, they would probably be mounted in the pontoons, to take account of the need to be able to operate at any draft. Access to pontoons is only available through the columns down vertical ladders. It is therefore likely that appreciable delays could be introduced by the time taken by users to get from their normal positions in the unit to the abandonment position.

The design of systems to provide for transfer of craft from dry, one atmosphere conditions to sea water under pressure involves significant complications. This is particularly true if the craft are to contain human beings. Accordingly, though no details of such designs have been studied, it seems likely that they will involve significant design and operating complications.

The systems would not be affected by low external air temperatures or icing conditions.

Part of the objective of such systems is to reduce the effect of wave height and wind speed. It must therefore be assumed that they would achieve this objective so that the former had little, if any effect and the latter none at all.

It is thought likely that the system could be designed to be unaffected by fire or gas. It is, in any event, unlikely that either would affect the area of abandonment for such systems in any but the rarest circumstances.

The design of the system is unlikely to involve unacceptably high accelerations.

8.3.6 PROD Launch[2]

This system is the result of research into methods of ensuring that conventionally single and twin fall launched TEMPSC are not swept into the structure of semi-submersible or jack-up MODUs in high sea states and winds. The early concept involved the use of a tag-line suspended from a rigid horizontal boom extending at right angles to the side of the parent unit at the launch position. The tag-line would be pulled through sheaves on the boom as the craft was lowered, against a constant tension. It would be attached to the bow of the craft and would therefore tend to pull this away from the side of the parent unit, thereby reducing the yawing motion of the craft introduced by high winds. On release, the craft would be pulled clear of the structure by the tension in the tag-line and continue to move forward under its own power until the tag-line connection automatically disengaged from it.

A diagram of the arrangement used in model tests for a single fall tag line system is shown in Figure 6. The model tests showed that setback into the structure could be reduced from one to half a boat length.

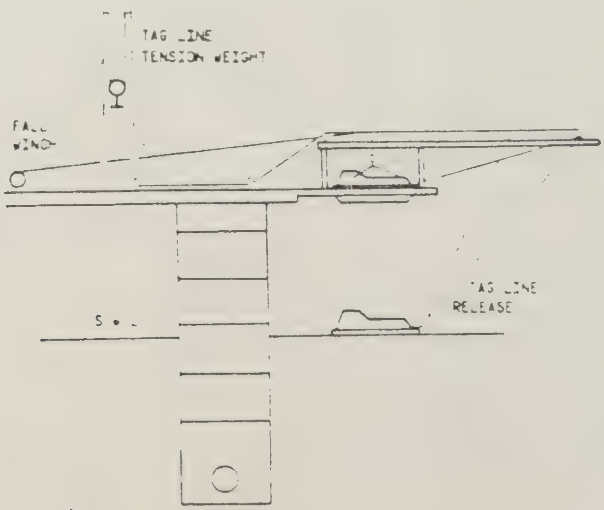


FIGURE 6 DIAGRAM OF THE SINGLE FALL AND TAG-LINE SYSTEM

By substituting the constant tension tag-line and rigid boom arrangement with a flexible boom pivoting about an axis parallel to the TEMPSC keel with a fixed length of tag-line attached to its outer end, similar results have been achieved in terms of setback but improved response to the motion of the TEMPSC in waves has been achieved.

This system is still under development but appears to offer a possible modification to existing single and twin fall systems which, without increasing the complexity of operation, will improve their performance in clearing the TEMPSC from the parent unit once it is in the water. They do not, however, fully overcome the limitations of ensuring that the TEMPSC clears obstructions during lowering if the parent unit has a severe list in the opposite direction. This can only be achieved by mounting the launching system well outboard so that its geometry achieves this objective.

8.3.7 Boom Launch

Several versions of a system similar to that designed for launching the 'Lifescape' but without final free fall have been proposed. Model tests of one such system were carried out with a lightly loaded tag-line attached to the TEMPSC stern to keep it head to wind. The system proved surprisingly successful in 17 metre waves with breaking crests but some difficulties, particularly associated with the TEMPSC being struck by the boom on release, were met. The designers concluded that the system, despite its exceptional ability to launch a TEMPSC clear of a listing structure in heavy seas, is probably of limited application on the grounds of weight and cost, which in part result from the requirement for the boom to survive continuous loading[2].

8.3.8 Guide-Wire Launch

Some twin fall launching systems use guide-wires, from the davits to either submerged parts of the parent unit or to points on the sea bed, possibly via blocks rigged from submerged parts of the structure. No record of the latter having been fitted has been found but the former have been employed on several units. The TEMPSC is attached fore and aft to a guide-wire by a form of snatch block.

The objective is to steady the TEMPSC during launch and to ensure that it clears obstructions whatever the attitude of the parent unit.

No reports have been found of trials of this type of system although it is understood that on several units their use has been discontinued because of the difficulty of re-attaching the TEMPSC to the guide-wires after drill use. Though they would probably achieve their objectives they might well make clearing the parent structure on release more difficult and so less likely to be satisfactorily achieved.

8.3.9 Off-Load Disengaging Gear

Most boat shaped TEMPSC are currently fitted with this type of gear. Before it can be operated, the load must be off the falls. In practice, this may only occur for brief periods if a craft is launched in heavy weather and accordingly the gear has proved unreliable. In two evacuation incidents in the North Sea (Ocean Express and Alexander L Kielland) of four craft where attempts were made to use this type of gear only one operated successfully. Both these incidents occurred in rough weather and better results can be expected if the weather is calmer. Nonetheless it is clear that this type of release gear may well introduce a form of 'obstruction' to successful launch and clearing of the structure.

8.3.10 On-Load Disengaging Gear

This type of gear is fitted in most disc shaped TEMPSC, combined with single falls. Though it does not suffer from the same releasing problems as off-load gear, the fact that it is designed to be operated on-load means that it is possible to operate it when the craft is still well above the water, as happened in the Ekofisk A incident (see paragraph 4.4.5).

However, the performance of this type of gear has in practice been better than off-load gear. Of a sample of seven craft launched using this type of gear, only one case is recorded of it failing. Accordingly, this type of release system seems less likely to present a form of 'obstruction' when abandoning a MODU.

8.3.11 Boat Shaped Survival Craft

At present there are two main manufacturers of boat shaped survival craft, who have supplied all such craft fitted in MODUs and supply ships (they are unsuitable for helicopters). Though details of design differ, for the purposes of this study the capabilities of each are sufficiently similar as to warrant consideration jointly.

The arrangements for launching TEMPSC have been examined in the preceding paragraphs. In this paragraph we examine their capabilities as survival systems.

TEMPSC are designed to right themselves even if they are capsized providing survivors are properly strapped in. Therefore, though they may capsize in waves higher than 8 metres, this should not introduce an excessive risk of survivors drowning. Current TEMPSC may not

right themselves if they are flooded internally (as a result of damage or for any other reason). The only TEMPSC from Ocean Ranger which was found with survivors alive onboard it suffered this fate[13]. The new Chapter III of the SOLAS Convention requires lifeboats which do not right themselves to have an above water escape route for those inside to climb out. Though this does not apply to MODUs, it is most unlikely that MODU owners won't seek the same capability. Though a step forward, this requirement is unlikely fully to safeguard survivors from drowning. To do so it is necessary to ensure that, even if holed and flooded, craft are self-righting, float high enough to keep heads above water and allow limited movement.

From the facts available, it appears that present TEMPSC give adequate protection from drowning provided they are launched effectively and remain clear of obstructions. Craft which meet the new SOLAS Convention will marginally improve chances of survival if they are flooded internally though only if rescue is at hand.

Present TEMPSC are only warmed internally by the heat of the engine. This would not necessarily be run at all times when awaiting rescue. Indeed fuel capacity is usually only available for 24 hours operation at cruising speed, though the engine could be run at idling speed for considerably longer. Furthermore, engines are, by precedent, not entirely reliable (see paragraph 8.3.1). Accordingly, it is possible that the ambient temperature inside TEMPSC in the conditions under review (air temperature -20°C to +11°C) may well drop to a level which would cause hypothermia in survivors within four days if they were not themselves wearing thermal protective clothing. This will be even more likely if the craft is damaged and becomes flooded.

Only if TEMPSC become flooded internally in a very rapid manner is it likely that cold shock would be suffered by survivors. Even in this unlikely event, survivors would be protected by suitable thermal protective clothing.

The air temperature inside TEMPSC may drop to below -0.55°C. Water will enter if the craft is damaged or a hatch is not properly shut. There is therefore a chance of survivors suffering freezing cold injuries which would be eliminated if proper thermal protective clothing covering all areas of skin were worn.

Non freezing cold injuries and cold incapacitation are likely to be suffered by any survivors in TEMPSC off the Canadian east coast if they remain in them for prolonged periods without running the engine or wearing thermal protection over their entire bodies, including extremities.

MODU-mounted TEMPSC are equipped with high pressure air bottles to provide clean air for survivors to breath for ten minutes. Means to ventilate the craft and so prevent a build up of CO_2 and shortage of oxygen are available. Exhaust gases from the engine are led overboard by a short route. Spark arrestors are fitted to exhaust systems to prevent ignition of flammable gas.

Supplies of anti-seasickness drugs can be available, though in many cases they are not included. Means of taking them without exposing body or limbs to the elements are not available.

TEMPSC are fitted with sea water spray nozzles which can cover the upperworks with a film of water to protect them and their occupants from fire. Tests of

such craft are carried out periodically by their builders to ensure the effectiveness of the systems. In trials carried out in Japan in 1983 using TEMPSC constructed of glass reinforced plastic, the craft was placed in a tank of flaming kerosene at a maximum temperature of 900°C with water sprayed at a rate to give a water film thickness of 0.7mm. The average temperatures of the inner surface and the inboard air were 110°C and 60°C respectively[7], which exceeds that set in the criteria. However, tests of another production TEMPSC in burning oil registered an internal air temperature of 25°C. We believe it possible therefore, that the criteria for environmental temperature can probably be met in TEMPSC.

Lysine Asopressin or similar drugs are available but are not normally included in the inventories of TEMPSC, and suitable means of taking them are not available.

The correct operation of TEMPSC requires certain routine actions to be carried out and certain skills.

To clear the parent unit, the craft must be steered, on a preferably pre-determined course, possibly by compass. This requires some degree of skill only achieved by instruction and practice.

The above operating functions are not particularly complicated, and it is unlikely that they could be greatly simplified or that they introduce hazards to people with some training. Training in the operation of boat shaped rigid survival craft is available in certain countries. Its suitability is outside the scope of this report.

Communications during abandonment, survival and rescue

phases are currently provided by hand held VHF radios. Duplicate sets are available as back up. We believe that these radios should provide back up to fitted VHF radios installed in the craft.

Normal TEMPSC location equipment includes radar reflector (not radar transponder), distress beacon and flashing lifebuoy light. Highly reflective material and an audible signal generator are not usually contained.

Initial trials on a self-deploying tow-line for TEMPSC are known to have been carried out. However, as currently equipped, these craft are not fitted with such equipment (except a strong point in the bow to rig a tow-line from outside the craft), nor are any other aids to transfer the survivors from TEMPSC to rescue vessels. Transfer of stretcher cases can only be carried out in very favourable conditions.

8.3.12 Disc Shaped Survival Craft

There is currently only one manufacturer of such craft whose product is used in MODUs. Their performance is similar to that of boat shaped craft in many respects. Accordingly comment is only made on areas of apparent difference.

Because these craft are designed for MODUs and offshore platforms and not for normal merchant ship use, they are not covered by the SOLAS Convention and so do not currently have an above water escape route for survivors if they capsize.

The fact that disc shaped craft are basically circular in plan form, and are propelled in such a way that their heading is unimportant, means that they can

propel themselves directly away from a structure regardless of their heading on entry to the water though, like boat shaped craft, they rely on their engines to do so. It has been said that they are more difficult to handle than conventional boats, though training and experience can improve this. Such training is available in the same way as for boat shaped craft.

8.4 INFLATABLE SURVIVAL CRAFT

The use of inflatable survival craft originated in the Second World War when they helped save the lives of many aircrew. Their use in ships and boats as well as aircraft has increased over the years to the extent that they are now found in almost all vessels and aircraft.

In MODUs and supply ships they supplement TEMPSC but in helicopters they form the primary means of survival for crews and passengers of aircraft ditching at sea. They vary in size from craft designed to carry single survivors up to those which are certified to accommodate up to 25 people and can, in extreme circumstances, carry up to twice this number. Modern designs are self inflating and contain integrated canopies. They are normally stowed on deck in canisters and are either launched direct into the sea, where they automatically inflate, or are inflated on deck and launched with their survivors onboard by means of davits. In offshore use, the former system is most common in MODUs but each is examined below.

8.4.1 Standard Liferaft

These liferafts are commonly found in MODUs, supply ships and helicopters. They are designed to act as a

refuge for people in the water and are only entered from the water or, conceivably, from a very low stage or deck in calm conditions. They therefore rely for practical purposes on abandonment of a unit having been achieved by some other means. In the case of MODUs, this may have been by climbing off a deck where it becomes submerged in heavy listing conditions, possibly by jumping, although this is very hazardous, or by climbing or swinging down some available rope or other route. In supply ships it will almost inevitably be jumping. In helicopters, survivors can normally reach the water directly through escape doors. However, their own successful launch must be judged against relevant abandonment criteria as well as their use being judged against survival criteria.

Liferaft containers or valises can be jettisoned safely at any deck angle up to at least 40°. To jettison them from helicopters should not present problems unless the aircraft is inverted.

Typical liferafts can be launched from up to 36 metres above sea level.

Launching systems do not require external power supplies.

Standard liferafts can only be launched by being dropped from their stowage into the sea. Accordingly, if there are obstructions below the drop point, possibly because of major list in the parent unit, they are not capable of launching. They can only be paddled clear of the parent unit and may therefore drift under it in unsuitable conditions.

Because they can be stowed in relatively small canisters (typical container for 25 man liferaft is

cylindrical, 1625mm length x 585mm diameter), the space required for each unit is limited. Accordingly they can be dispersed around a parent unit in a manner to take account of the 'capacity criteria'.

Launching of standard liferafts can be achieved in a matter of seconds.

The launching of standard liferafts and their subsequent inflation is simple to achieve and involves only a few separate mechanical operations.

The inflation of life rafts in very low ambient temperatures introduces particular problems. At such temperatures liquid carbon dioxide which is usually used for inflation, does not change state and so inflate the life raft quickly. Air is nowadays often used instead but, though very rapid and reliable in normal use, can become as ineffective as carbon dioxide in very cold temperatures. Nitrogen has, however, been found to be effective and provides efficient inflation in air temperatures down to -20°C.

In 1981, trials of liferafts off Iceland proved that, with suitable shaped drogues or sea anchors, liferafts can remain stable in wind speeds gusting to 65 knots and 'very rough seas' in excess of 10 metres[8]. However, if their ballast pockets do not fill within 25 seconds the raft can fly on its drogue painter like a kite[8].

Even if they remain stable in these conditions, they will only do so if the drogue is deployed and it is unlikely that they will avoid capsizing during inflation. Likewise, without the drogue deployed, they will drift down wind fast. Accordingly it does not seem

that their launching characteristics meet the criteria for abandonment concerning wind and waves.

Because standard liferafts are boarded by survivors in the water, they must be visible to survivors. In zero visibility this would not be possible.

Liferafts cannot provide protection, or survive themselves, in areas of fire.

Liferafts are not capable of safe operation in irrespirable gaseous environments but, providing suitable precautions are taken by users, they can be operated safely in combustible gaseous environments.

Standard liferafts do not subject users to excessive accelerations.

Their simple use ensures that training in launching liferafts does not need to be extensive. If used for drill purposes, they must be repacked professionally unless test liferafts are used.

Communications between launch point and other relevant centres are normally provided by portable VHF radio. Instructions can be received by tannoy or light or sound signals.

Rapid and extreme changes of temperature are not applied to users of standard liferafts by their use per se but because they must normally expect to board the liferaft from the sea, such extremes may have been suffered when entering it.

During abandonment the core temperature of survivors depends upon equipment other than standard liferafts.

No danger from electric shock exists during abandonment.

There should be no requirement for extreme physical exertion by users, though incorrect drill for righting capsized liferafts or entering them can cause considerable physical exertion.

The launching of standard liferafts and their entry do not introduce hazards associated with breathing.

Liferafts prevent their occupants from inhaling water by protecting them from waves and spray. If they capsize, this protection is likely to be lost. Providing survivors can enter liferafts successfully, trials have shown that they can remain upright, if they have suitable drogues deployed, up to wind speeds of 65 knots and 'very rough' waves well in excess of 10 metres[8]. They may be stable in worse conditions than this.

The temperature inside liferafts is maintained by the body heat of survivors and retained by the canopy and double skinned bottom. Trials off Denmark in 1979 showed that keeping warm was not a simple matter and could best be achieved by survivors undressing and lying together under blankets[9]. No records of the ambient temperatures during these trials has been obtained but it is unlikely that they were as low as -20°C. It is most unlikely that without thermal protective clothing in temperatures below 0°C, core temperatures of survivors would be retained at 35°C or over for more than a few hours. It is also possible that without suitable protective clothing, survivors could suffer from 'freezing cold injuries', 'non-freezing cold injuries' and 'cold incapacitation', though not from 'cold shock'.

To retain warmth within liferafts their ventilation flaps should be kept shut. However, in this condition, the level of CO_2 is likely to build up to dangerous proportions. The safety of survivors therefore depends upon them being protected from cold to the extent that the ventilation arrangements can be operated. Life-rafts offer no protection from gas or burning oil.

Conditions in liferafts are very conducive to seasick-ness. Anti-seasickness drugs are not always included in inventories.

No protection is provided against fire.

Liferaft inventories do not always include supplies of Lysine Asopressin or similar drugs.

Liferafts are simple to operate although certain set actions are required. No great dexterity is required.

Limited communications arrangements are normally provided in liferafts, usually comprising simple battery powered VHF radios. These are sufficient to communicate with neighbouring liferafts but may well be insufficient to aid rescue forces.

Liferafts normally contain flares but no audible signal device, radio beacon or radar transponder.

Transfer from liferafts to rescue vessels relies upon means provided by the latter such as personnel strops and winches. In calm weather transfer direct to the deck of rescue vessels, if low enough, may be possible but in other conditions transfer poses considerable problems. Standard liferafts cannot be lifted from the sea by strops. They are usually fitted with towing pennants.

8.4.2 Davit Launched Liferafts

The liferafts launched from davits are in most respects similar to standard liferafts. Their principal difference is that they are strengthened and equipped with built-in slings which enable them to be lifted from a central point at the top of the canopy. They are normally stowed near their davits in canisters. To use them, liferafts in their valises are removed from their canisters and attached to the davit single fall. They are then swung outboard with steadying lines attached to a point at the deck edge. When clear they automatically inflate clear of the valise and can be boarded direct from the deck. They are then lowered to the water controlled either from the davit or from inside the liferaft. Release from the davit fall can be either by manually operated or automatic off-load slip.

In assessing davit launched liferafts against the abandonment and survival criteria, reference is only made to aspects in which they differ from standard liferafts.

Launching davit launched liferafts is rather more complicated than standard liferafts though limited training is sufficient to ensure it being done correctly. No statistics have been obtained of failures of launching systems.

Though no published data have been obtained concerning maximum wave heights into which liferafts may be launched using davits, it seems likely that the lack of control of the craft on release will make it prone to drifting under the structure if launched to windward in high sea states. If launched to leeward, it is

possible, though by no means certain, that it could survive launching into 17 metre waves.

High winds will cause the craft to swing on the fall. This may bring it into contact with parts of the parent unit and though damage and injury are possible, they are unlikely to cause complete failure[10].

Low visibility has no effect on the success of abandonment by davit launched liferaft.

8.5 INDIVIDUAL ABANDONMENT AND SURVIVAL

Individual abandonment of a rig may come about in one of several ways. The man concerned may find himself still on the rig after everyone else has left, using all the major life saving appliances. He may find himself in a position on a rig from which there is no access to major units of life saving appliances, as a result of the accident which caused the emergency. The damage may have been so severe that major life saving units are not able to operate. Or he may abandon individually because that is the abandonment and survival philosophy adopted by the owners of the rig.

There is a school of thought which suggests that individual abandonment is the preferred solution though no one has yet adopted it. Of the other three accidental reasons, instances can be quoted for two of the cases. An unignited gas blow-out occurred on a North Sea platform and orders for abandonment were given. Three men went about the business of shutting down and making the platform as safe as possible. On going to their abandonment station they found that all life boats had left. Fortunately the sea was unusually calm and they were able to attract the attention of a boat crew who returned and picked them up from ropes down which they descended.

Damage to the Alexander L Keilland was such that the rig took an immediate heavy list, immersing one deck edge. Many men entered the water individually directly from the rig's deck.

If the philosophy of individual abandonment were to be adopted it would be necessary to devise something rather more sophisticated than a survival suit and a life jacket for each man. Those proposing this method have in mind a one man dinghy after the style used by fighter pilots. Beyond mentioning that this is a possibility it is not intended to examine the idea in depth. It has one major

disadvantage which is that there would be no positive way of clearing the rig (or any burning oil in its vicinity) and in fact men may drift underneath the rig and have it sink or capsize on top of them. A further problem would be how to get the men safely into the water from the height of the rig unless the philosophy included waiting until the rig sank and then floating off. A further disadvantage of this approach concerns the final rescue of large numbers of individuals from the sea. This would introduce considerable problems, particularly if they had become widely dispersed.

It is intended to regard individual abandonment as a system within its own right but at the same time to regard it very much as a last resort, which would be undertaken if none of the more sophisticated systems were available. It is assumed that under two out of three of these circumstances the rig would be in a sinking condition and access to the water would not be a problem. In the case of a man or men 'missing the boat' they would need a means of access to the water which should always be available but this could be of a simple type since not more than a few men would be involved and then not intentionally. Rope ladders or rungs attached to columns are envisaged, though several more sophisticated arrangements ranging from folding stairways to constant speed winches and strops are available.

In the case of helicopter crews and passengers, and supply ship crews, the philosophy is similar, but it is considered more likely that survivors will get wet during the course of getting into their rafts or boats, which currently are the primary means of abandonment and survival from these units. It follows therefore that all persons on MODUs, supply ships or helicopters need to be able to enter the water during the course of any abandonment, even though many of them would hope to board a prime life saving appliance at some time before they were ultimately rescued. Survival suits and life jackets (either separately or as integral garments) provide the protection required to achieve this.

Extensive testing programmes have been set up by a number of bodies, for the purpose of evaluating survival suits. Whilst these tests are useful in that they compare suits under controlled conditions, they do not give an accurate picture of how long a man wearing one will survive in cold water with wind and waves upon it. Tests have concentrated upon ability to keep a man's core temperature at survival level and ability to keep a man afloat without taking account of the many other factors involved in survival.

Tests on currently available survival suits[11 & 12] indicate that, generally speaking, waterproof insulated suits were most successful in maintaining core temperature at survival level. Wet suits and dry suits without insulation were not as good. A significant factor which emanated from the NUTEC report[12] was the rapid increase in core temperature drop resulting from water entering a 'dry' suit in large quantities. For example, an insulated suit capable of achieving an average hourly core temperature drop of 0.65°C allowed an average drop of 1.8°C per hour when water entered the suit.

Subjects wearing woollen underwear inside non-insulated suits had similar rates of temperature drop to those wearing some kinds of insulated suit.

Personal factors of individual subjects made a difference to performance of suits of the same specification.

Life jackets are the abandonment tool most likely to be immediately available to a man needing to abandon a rig. Various types are available and may be broken down into four basic types. The first of these is the non-inflatable, permanently buoyant type. The other types are all inflatable. One is orally inflatable only and therefore a man must be able to inflate it himself either in the water or before he enters the water, depending upon circumstances. Another type may be inflated by means of a CO_2 gas

cylinder operated by the wearer pulling a toggle. The final inflatable type inflates automatically upon contact with salt water. Both CO_2 inflatable types may be topped up, or completely inflated, orally.

In assessing individual abandonment and survival systems against the criteria in sections 5 and 7, it is not intended to compare each individual type of system but rather to see whether the criteria can be met by any. This is done below.

The angle of the deck of the unit being abandoned is not critical.

The deck height is critical if no means are available to transport the person abandoning a unit from it to the water. Means are only available to cater for clement conditions.

Recourse to the parent unit's normal supplies of electricity, hydraulic or pneumatic power is not required.

The NUTEC trials[12] showed that some survival suits having high integral buoyancy, particularly as a result of entrapped air, presented difficulties to people attempting to escape from a partly flooded helicopter cabin, since forcing themselves down in the water to pass through a submerged escape hatch was a problem. An already buoyant life jacket would also present a similar problem under those circumstances. The same could apply in ship or rig accommodation if flooding had occurred and even if there was no flooding, bulkiness in confined spaces would be a disadvantage. Survival suits and life jackets are available which do not suffer these disadvantages.

It is possible to provide sufficient survival suits for all those on board MODUs, supply ships and helicopters.

The time taken to don survival suits varies with the design of the suit. In essence, the more comprehensive the

protection, the longer it takes to get into. In addition, it is impractical to stow or transport sophisticated and expensive survival suits indiscriminately around a unit. Accordingly much time may be needed for individuals to go to the location of their survival suits in times of emergency. By adopting a procedure whereby in MODUs and supply ships primary survival suits are supplemented by stocks of secondary survival suits (see para 6.2.2) which are placed suitably about the upper deck, the criterion set for response time can be met by existing survival suits. To meet the criterion affecting helicopters, it is necessary for passengers to be wearing their survival suits throughout flight though for comfort, zips may be left unzipped. During the NUTEC trials it was found that one type of survival suit had a flap in the side which tended to stick in the zip. If the zip was not done up before an emergency, this could introduce too much delay.

Most individual survival equipment is simple to operate. Survival suits are available capable of protecting users within the range of temperatures specified. Some depend for this upon survivors also wearing normal clothing inside them.

It is unlikely that survivors entering the water individually by any means would be safe in waves of 17 metres or wind speeds of 70 knots. It is very possible that they would be thrown against some member of the parent structure before getting clear of it.

Individual abandonment is unaffected by low visibility.

Some survival suits provide short term protection against passing quickly through a flash fire. However, none provides protection against fires with temperatures of up to 1,000°C. Most survival suits would provide temporary protection from conditions of radiant heat from normal sources.

No individual abandonment and survival means offer protection in irrespirable or combustible gaseous environments.

Unless they jump from a considerable height directly into the water, individual survivors are unlikely to suffer accelerations outside the limitations shown in the criterion.

The existence of suitable communications arrangements will depend upon individual circumstance in each unit.

Providing they are properly worn, survival suits are available which prevent rapid and extreme changes of temp-rature and limit ingress of water to less than 5 litres per hour.

Extreme physical exertion is not required.

No breathing systems are provided.

Many survival suits do not provide buoyancy in such a way as to prevent survivors lying face down in the water. Further-more, it has been found that intrinsic buoyancy in a survival suit as a result of unintentional air entrapment can also cause the wearer to float at an angle which does not keep his face as clear of the water as would be desired. However, suits and life jackets are available today which do not suffer from either of these limitations, although there is still room for improvement. No currently available commercial suits properly protect the wearer from inhaling spray or water in rough windy conditions, whether he is conscious or not. In fact it is unlikely that any would successfully do so even if he is definitely conscious. Submarine escape suits in current use with the Royal Navy incorporate a plastic shield to the front of the hood. With the zip fully closed the man's face is totally covered and the suit is worn thus during the ascent from a sunken submarine. When on the surface the surviver opens the zip slightly to allow air from outside to be breathed. However some water may then get into the hood. A development of this system has been designed by Bristol Uniforms Limited which incorporates two holes in the top of a hood which has

a transparent visor over the face. The hood is attached to a life jacket and early trials indicate that it shields a survivor's face successfully from spray and breaking waves whilst allowing circulation of air to prevent suffocation. So far this arrangement is only available in prototype form.

The NUTEC[12] trials indicate that four units are capable of containing the rate of core temperature drop to 0.5 C° per hour or less. Three suits which were included in trials by DCIEM, Downsview, Ontario, at the request of the Chief, Air Doctrine and Operations, Canadian National Defence Headquarters, had the same capability. NUTEC tests where zips were not closed showed that cooling rates with water in the suits were much higher, ranging from 0.7 C° to 1.85 C° per hour.

Few figures for cooling rates achieved by secondary suits are available. Trials of two such suits used in Canada indicated rates around 1 C° per hour. Moreover, because it is reasonable to assume that they will allow a faster ingress of water than primary suits, the sort of figures obtained from suits which were badly zipped can reasonably be used as an estimate for secondary suits. This would also suggest that a rate of about 1 C° per hour could be expected with these suits. From these figures we can deduce that primary suits and secondary suits are available which meet the criterion.

Currently available suits will protect survivors against cold shock.

To protect survivors against freezing cold injuries and non-freezing cold injuries, extremities must be insulated from the sea water. Most suits provide insulation for the feet. Separate gloves are available though by no means always provided. One suit is known to provide integral covering for the hands as well as the feet though not to leave them free for use, which may itself hamper survival. The hood, described as a shield to prevent ingress of spray and water

into the airway, provides some protection to the face from freezing and non-freezing cold injuries. The criterion concerning air breathed is related principally to life craft.

Anti-seasick drugs are available but no suits which contain them, or of means to administer them without exposing parts of the body to the elements, have been found.

No suits containing supplies of Lysine Asopressin or similar drugs, or of means to take them without exposing parts of the body to the elements, have been found.

Some suits provide means to ensure that individual survivors can be retained close to each other, although by no means all do.

Communications between individual survivors can only be achieved by voice or whistle. This is unlikely to be of much use.

Most survival suits and/or life jackets contain an integral battery powered light. Some suits have highly reflective material markings.

Whistles are usually included. Radio directional beacons are not currently provided for groups of survivors, nor is a buoy mounted unit currently in use, though such units are available. Survival suits are not currently designed to provide for lifting survivors in the foetal position.

It is thought likely that the different requirements for helicopter survival suits and those used in MODUs and supply ships will result in different types of suits being chosen. In principle, helicopter suits need to be worn throughout flight, to be non-buoyant until the survivor is clear of the helicopter and to be robust enough to be used several times a day. On the other hand survival suits for use on MODUs and supply ships are likely only to be used once and will not need to be worn except for abandonment and survival.

Section 8 - Reference

1. Night and Poor Weather Helicopter Offshore Operations - Dr J N Barrett. Offshore Helicopter Operating Safety Seminar 1982.

2. Development of Lifeboat Launching Systems for Offshore Rigs and Platforms - I M C Campbell, A R Claughton and A R Kingswood - International Conference on Marine Survival Craft, November 1983.

3. Risk Assessment of Emergency Evacuation from Offshore Installations - prepared for UK Department of Energy by Technica.

4. Design of Freefall Lifeboat Systems - P Werenskiold - International Conference on Marine survival Craft, November 1983.

5. Free Fall Lifeboats for Offshore Production Platforms, Part I. NSFI Project Report No. PR39220500 of January 1982.

6. An Offshore Safe Haven Concept - B Bengtsson - International Conference on Marine Survival Craft - November 1983.

7. Fire Proof Lifeboats of Reinforced Plastics - O Nagata - International Conference on Marine Survival Craft - November 1983.

8. Full Scale Trials of Inflatable Liferafts - E J Forman - International Conference on Marine Survival Craft - November 1983.

9. Design and Prototype Experience of Catamaran Type Rescue Boat/Capsules - Capt Unden - International Conference on Marine Survival Craft - November 1983.

10. Impact Tests of Davit-Launched Inflatable Liferafts - D O Ellingsen - International Conference on Marine Survival Craft - November 1983.

11. Survival Suits for Accidental Immersion in Cold Water - Design Concepts and Their Thermal Protection and Performance. University of Victoria, January 1978.

12. Tests of Survival Suits for Offshore Helicopter Transportation - NUTEC November 1982.

13. US National Transportation Safety Board Draft Marine Accident Report 'Capsizing and Sinking of the US Mobile Offshore Drilling Unit Ocean Ranger off the East Coast of Canada 166 Nautical Miles East of St John's, Newfoundland, 15 February 1982'.

9. SUMMARY OF CAPABILITIES OF MEANS OF ABANDONMENT AND SURVIVAL

The conclusions of the assessment of the means of abandonment and survival which are contained in Section 8 are summarised in Tables 7 and 8 below which provide the basis from which to assess current means of abandonment and survival from MODUs. It is clear from Table 8 that survival is reasonably assured if abandonment can be by helicopter or dry transfer.

9.1 HELICOPTER

By reference to Table 7 we can see that abandonment by helicopter is possibly limited by deck angle, response time (up to four hours), visibility (less than 1,000 yards by day or 10,000 by night), fire and gas.

The limitation concerning rotor start-up in wind speeds of over 50 knots (or for Chinook 35 knots) should not affect shore based helicopters or helicopters on decks where a lee can be provided. If reasonable warning of need to abandon (over four hours) is available, the unit is not listing beyond helicopter capabilities and fire or gas do not present hazards, limitation of visibility is the most likely cause of helicopters being unable to evacuate personnel (providing the assumptions made concerning response time are met). Visibility is likely to be less than 1,000 yards for the proportion of the time indicated in Table 9 below during each month in each area. Visibility of 10,000 yards will occur for a smaller proportion of the time so this has not been estimated.

In Table 9 forcasts of 10% and more of the time being subject to visibility of 1,000 yards or less are shown in thick type. This alone indicates the high level of poor visibility to which the Eastern Canadian seaboard is subject.

	Deck Angle	Deck Height	Power Supplies	Obstructions	Capacities	Response Time	System Op	Air Temperature	Wave Height	Wind Speed	Visibility	Fire	Gas	Accelerations	Communications	Temp Changes	Environmental Temperature	Electric Shock	Extreme Physical Exertion	Breathing Systems
Helicopter	20°	S	S	S	S	4hr	S	S	S	*	**	No	No	S	S	S	S	S	S	S
Dry Transfer	S	S	S	S	S	1hr	S	S	S	S	100'	No	No	S	S	S	S	S	S	S
Davit TEMPSC	No ***	S	S	No	S	S	S	S	8m	50 kts	S	S	S	S	S	S	S	S	S	S
Freefall TEMPSC	20°	S	S	S	S	S	S	No	9m	S	S	S	S	S	S	S	S	S	S	S
PROD TEMPSC	No ***	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
'Lifescape'	17°	S	S	S	S	S	S	S	12m	S	S	S	S	S	S	S	S	S	S	S
Submerged Launch	?	?	S	S	S	No	No	S	S	S	S	S	S	S	S	S	S	S	S	S
Individual Systems	S	?	S	No	S	S	S	S	No	No	S	No	No	S	S	S	S	S	S	S
Inflatable Craft	No	S	S	No	S	S	S	S	No	No	No	No	No	S	S	No	No	S	S	S

* Helicopters limited by wind speed only for start-up ; 50kts limit for all except Chinook which is currently limited to 35kts.

** Visibility for helicopter operations limited by day to 1,000 yards and night 10,000 yards except where specially equipped, or under Instrument Flying Rules.

*** Deck angle for TEMPSC launched by standard davits and PROD system possibly limited by obstructions from structure if parent unit heeling.

S = Satisfactorily meets criterion.

TABLE 7 SUMMARY OF ABANDONMENT SYSTEM CAPABILITIES FROM MODUs

	Drowning	Hypothermia	Cold Shock	Freezing Injuries	Non-Freezing Injuries	Cold incapacitat-ion	Air Breathed	Sea Sickness	Burns	Body Fluid	Ergonomic	Communications	Location	Transfer
Helicopter	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Dry Transfer	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Davit TEMPSC	S	No*	S	S	No*	No*	S	No	S	?	S	No	No	No
Freefall TEMPSC	S	No*	S	S	No*	No*	S	No	S	?	S	No	No	No
PROD TEMPSC	S	No*	S	S	No*	No*	S	No	S	?	S	No	No	No
'Lifescape'	S	?	S	S	?	?	S	?	S	?	S	?	?	?
Submerged Launch	S	?	S	S	?	?	S	?	S	?	S	?	?	?
Individual Systems	No**	S	S	No	S	S	No	No	No	No	S	No	No	No
Inflatable Craft	S	No*	S	No*	No*	No*	?	No	No	No	S	No	No	No

* The capabilities of systems to cater for the requirements so marked are insufficient unless survivors are wearing suitable survival suits.

** Current survival suits/lifejackets do not incorporate 'spray hoods' though a prototype of such a hood now exists.

S = Satisfactorily meets criterion.

TABLE 8 SUMMARY OF SURVIVAL SYSTEM CAPABILITIES FROM MODUs

Month \ Area	1	2	3	4	5	6	7	8	9	10	11	12	13	14
January	6.7	9.8	**11.3**	**11.9**	7.5	7.7	5.8	6.1	5.3	5.8	4.3	3.8	3.9	3.4
February	7.0	**11.8**	**11.4**	**10.1**	6.0	8.3	6.9	7.3	6.2	5.5	5.4	4.5	4.5	3.4
March	4.4	9.0	**13.7**	**13.3**	**12.0**	**12.2**	9.4	9.8	8.5	6.0	6.2	6.7	6.6	5.4
April	4.5	**11.2**	**8.5**	**12.6**	**13.5**	**16.2**	**17.5**	**12.0**	**14.6**	6.3	5.6	9.2	8.7	6.6
May	**11.1**	**19.0**	**21.5**	**22.6**	**21.5**	**20.6**	**25.2**	**20.3**	**23.6**	6.8	6.5	**15.5**	**19.3**	**11.3**
June	**12.1**	**20.6**	**16.4**	**19.5**	**27.5**	**31.9**	**34.3**	**23.3**	**31.6**	8.6	7.3	**20.3**	**24.3**	**17.7**
July	**10.6**	**17.0**	**17.2**	**21.5**	**39.9**	**46.3**	**39.5**	**26.1**	**38.3**	**11.8**	7.5	**28.1**	**30.5**	**28.8**
August	**10.1**	**17.5**	**17.2**	**15.6**	**19.0**	**25.0**	**22.5**	**14.1**	**21.3**	**7.3**	3.1	11.5	**15.5**	**25.7**
September	**10.1**	**14.0**	8.8	9.7	**10.8**	**13.9**	**12.0**	7.1	**10.9**	4.9	3.6	5.2	5.8	**11.4**
October	**10.0**	**14.5**	8.9	8.1	**10.2**	**11.4**	9.8	6.5	8.2	3.0	2.7	4.3	4.5	7.5
November	9.4	**14.2**	8.1	7.5	9.6	9.8	8.0	6.2	7.2	2.5	4.5	3.8	4.5	3.5
December	7.2	**12.8**	8.7	6.6	7.9	7.6	5.2	7.0	4.6	4.6	5.1	2.9	3.7	5.3

TABLE 9 PERCENTAGE FREQUENCY OF VISIBILITY LESS THAN 1,000 YARDS

In areas 6, 7, 9 and 13, some months record figures of over 30% for visibility of 1,000 yards or less. It is correspondingly likely that evacuation by helicopter will be impossible unless special equipment is fitted. Such equipment is available and used in many SAR areas (see paragraph 8.1.1).

How good is it?

9.2 DRY TRANSFER

Dry Transfer systems such as the one used as the basis for the assessment in Tables 7 and 8 are not yet in normal use, though one has been ordered for a North Sea fixed platform. They depend upon the availability of a suitable receiving vessel which must be large enough, stable enough and capable of holding a sufficiently accurate position. If such a vessel is available, successful abandonment and survival is likely providing one hour is available to complete abandonment and visibility is over 100 feet. In fact, this figure may be improved upon with further development of positioning systems for such vessels. Dry Transfer therefore offers good potential. However the cost is such as to make it hard to justify provision of a suitable vessel for each MODU operating off Eastern Canada and it is, therefore only likely to prove feasible for groups of MODUs or, in due course, platforms. The penalty of this cost-sharing approach will be an increase in response time, tied to the distance apart of units served by a common rescue vessel but this is an equation which will need to be solved.

9.3 LIFESCAPE

The capabilities of the 'Lifescape' in providing for survival are ill-defined in Table 8. This is because the final design is not yet complete. It is therefore possible that means will be available to cater for all the requirements. If so, it could provide for safe abandonment and survival except when the parent unit is listing over about 17° or maximum wave heights are over 12 metres. Table 10

Month \ Area	1	2	3	4	5	6	7	8	9	10	11	12	13	14
January	0	0	1.2	1.6	7.0	7.0	7.0	1.5	1.1	0	2.0	1.1	1.1	0.1
February	0	0	0.7	1.4	3.5	5.2	6.8	0.8	3.3	0	3.5	1.5	1.2.	0.2
March	0	0	2.0	0.8	3.3	3.3	3.3	1.9	0.6	0	0	0.7	0.6	0.6
April	0	0	0.1	0.3	1.1	1.3	1.5	0.1	0.5	0	0	0	0.1	0.1
May	0	0	0.2	0.3	0.6	0.5	0.4	0	0	0	0	0.1	0.1	0
June	0	0	0.2	0.2	0	0	0	0	0	0.3	0	0	0	0
July	0	0	0	0	0	0	0	0	0	0	0	0	0	0
August	0	0	0.1	0.2	0.1	0	0	0.1	0	0.2	0	0	0	0
September	0	0.1	0.1	0.1	0.8	0.5	0.1	0	0.1	0.3	0	0.2	0.1	0
October	0	0.3	0.9	0.5	2.2	1.9	1.6	0.2	0.1	0.2	0	0.1	0.2	0.2
November	0	0	0.4	0.6	3.3	2.6	1.8	0.1	0.3	0	0.3	0.9	0.4	0.1
December	0	0	0.7	0.7	4.0	3.8	3.6	0.6	0.9	0	0	0.8	1.4	0.7

TABLE 10 PERCENTAGE FREQUENCY OF MAXIMUM WAVES OVER 12 METRES

shows the monthly percentage frequency of maximum wave heights over 12 metres in each Area.

From Table 10 it can be seen that the greatest frequency of maximum wave heights exceeding 12 metres occurs in January in Areas 5, 6 and 7 when they may do so for as much as 7% of the time. In Areas 7 and 6 in February, the figures are 6.8 and 5.2 respectively. Otherwise they are always under 5% and, apart from Areas 5, 6 and 7 from November to March, under 2.5%. It is therefore likely that, if it comes up to its design specification, the Lifescape, or any other system with equivalent characteristics, would provide an acceptable means of abandonment and survival off Eastern Canada.

9.4 TEMPSC

Existing TEMPSC can provide for effective survival (if suitable survival suits are worn and suitable drugs to reduce loss of body fluid and to counter sea sickness are taken by survivors) except in relation to their communications, means of location and transfer arrangements.

The technology is available to overcome each of these deficiencies through additional radios, satellite linked emergency beacons and suitable towing arrangements. Suitably equipped TEMPSC, of current design, could therefore be expected to protect survivors in an acceptable manner. They are limited in abandonment by deck angle and, except with the as yet unproved PROD system, wave heights of 8 metres by davit launch and 9 metres by freefall (though the latter may be proved to be less restricted). In addition normal gravity davit launched TEMPSC are liable to be obstructed by failures of off-load release gear, by being swept under the parent units in some conditions and by unacceptable oscillation during lowering in wind speeds over

Month \ Area	1	2	3	4	5	6	7	8	9	10	11	12	13	14
January	0.0	0.0	11.1	19.0	20.0	37.6	46.2	11.5	28.4	5.2	3.4	8.7	13.1	2.0
February	0.0	0.0	10.5	16.6	19.4	34.6	43.1	12.8	27.9	6.8	6.2	13.7	13.9	2.4
March	0.0	0.0	10.0	12.9	15.2	25.3	29.6	12.0	20.8	1.5	1.2	7.3	10.8	1.1
April	0.0	0.0	11.1	10.0	9.4	17.6	22.2	6.0	13.2	0.0	2.2	6.3	6.5	0.9
May	0.0	1.5	3.3	5.9	1.3	4.6	7.2	1.9	4.6	0.5	1.3	1.3	2.1	0.1
June	0.4	1.0	2.7	2.4	1.4	2.1	2.1	0.7	1.3	0.3	0.0	0.4	0.4	0.0
July	0.0	0.5	0.3	1.4	0.5	1.5	1.9	0.3	1.0	0.2	0.0	0.2	0.4	0.0
August	0.0	1.2	1.0	2.6	3.1	1.0	1.5	3.4	1.0	0.4	0.0	1.1	0.6	+++
September	1.1	2.1	2.3	3.5	5.1	5.2	5.3	3.7	3.3	1.0	1.8	1.7	1.4	0.1
October	0.2	2.2	6.2	12.1	4.3	10.8	16.6	4.5	10.0	1.7	1.5	4.0	4.0	2.0
November	0.0	+++	5.7	12.6	9.7	18.4	22.8	5.2	14.6	2.6	3.6	6.0	8.9	1.4
December	0.0	0.0	8.5	18.7	9.9	29.2	36.4	16.1	22.9	2.7	7.6	9.7	13.8	3.7

+++ Denotes a percent frequency of less than 0.05 but not zero.

TABLE 11 PERCENTAGE FREQUENCY OF MAXIMUM WAVES OVER 8 METRES

50 knots. Free-fall TEMPSC are limited by icing conditions, though it is likely that this limitation could be overcome.

To obtain an indication of the availability of means of abandonment offshore Eastern Canada using systems as now fitted there, Table 11 set out the percentage frequency of maximum waves greater than 8 metres in each area. It shows that, in Areas 6 and 7, percentages of over 25% are expected throughout December to March, with as much as 46.2% in Area 7 in January.

It is important to remember that, in addition to the wave height limitations highlighted by Table 11, existing TEMPSC as fitted to MODUs may fail to save life because of the other limitations to which they are subject (see Tables 7 and 8). Adoption of the PROD launch system may well overcome the 'obstruction' limitations and 'wave height' and 'wind' limitations though it would not affect the limitations introduced by high angles of list or trim.

9.5 INFLATABLE CRAFT

Inflatable craft are already looked upon as a secondary (or, if helicopters are available, tertiary) means of abandonment and survival. Table 8 shows that, even if survivors are wearing suitable survival suits, survival may be jeopardised by sea sickness, burns, loss of body fluid or failure to be rescued resulting from deficiencies in communications, location aids or means of transfer. Each of these limitations could be overcome using existing drugs or equipment except the susceptibility of such craft to fire and the problem of transferring survivors to safety.

Abandonment into inflatable life rafts is subject to failures stemming from obstructions caused by list or trim angles; survivors being swept under the parent unit or life

rafts being swept away from survivors by waves or wind; low visibility preventing survivors in the water finding life rafts; fire or gaseous environment and cold air and water. In spite of these limitations, it would be a mistake to discount the possible value of inflatable life rafts as back-up systems to rigid craft or to neglect development of means to overcome the limitations mentioned.

9.6 SUBMERGED LAUNCH

Submerged launch is only a conceptual idea. Accordingly there is insufficient information to make clear predictions of its effectiveness as a means of abandonment or survival. Problems to be overcome are associated with deck angle, variable depth of launch point, response time, complexity of operation and possibly providing sufficient integral energy to prevent hypothermia, non-freezing cold injuries, cold incapacitation and loss of body fluid. Sea-sickness could require the use of suitable drugs, though if the escape vessel remained submerged this is unlikely. Communications, location and transfer would each require careful attention.

9.7 INDIVIDUAL ABANDONMENT

Individual abandonment and survival is currently a last resort, and is likely to remain so unless revolutionary advances are made in individual systems. Available survival suits and life jackets can provide protection against hypothermia in all Eastern Canadian waters for four hours if properly worn. However they are unlikely to provide the necessary protection from spray and waves breaking over the face in rough weather which is needed to prevent survivors drowning. A prototype hood and shield has been produced which, though not yet fully tested, shows signs of offering such protection. Individual survivors are vulnerable to irrespirable gases, sea sickness, burns and loss of body

fluid. Current means of communication, location and transfer of survivors to safety are also inadequate.

Abandonment by survivors individually may be achieved satisfactorily if the unit sinks or lists far enough for one part of the deck to be in or near the sea surface. If not, survivors must rely on such aids as ropes, rungs, chutes or expanding staircases, all of which present considerable hazard in bad weather.

It is important to continue to develop survival suits which provide good protection to wearers in very cold air and water, not only for individual abandonment but also to assist in survival for long periods (say several days) in TEMPSC and inflatable life rafts. Primary and secondary suits should be developed (see 6.2.2).

It is also possible that improved aids to individual abandonment could be of use but, because such abandonment is very much a last resort and would not be of use at the time of most likely need, that is when a unit sinks, it is not considered that as great emphasis should be put on developing them as on developing dry transfer systems.

9.8 DITCHED HELICOPTERS

Abandonment and survival from ditched helicopters relies entirely upon inflatable life rafts and survival suits and is therefore subject to their limitations as summarised above. However, the need to wear survival suits whenever airborne over water off Eastern Canada, brought about by the requirement for response time of three minutes, sets different criteria for such suits in terms of wearability than those designed for abandoning MODUs.

Suits are currently available which are designed for wear in helicopters which provide protection from hypothermia and shock, but which do not protect wearers fully from drowning, freezing injuries, non-freezing injuries, cold incapacitation, sea sickness or loss of body fluid.

Protection from irrespirable gases and burns is not deemed necessary for helicopter use. The suits suffer the same limitations in communications, location and transfer devices as those referred to above.

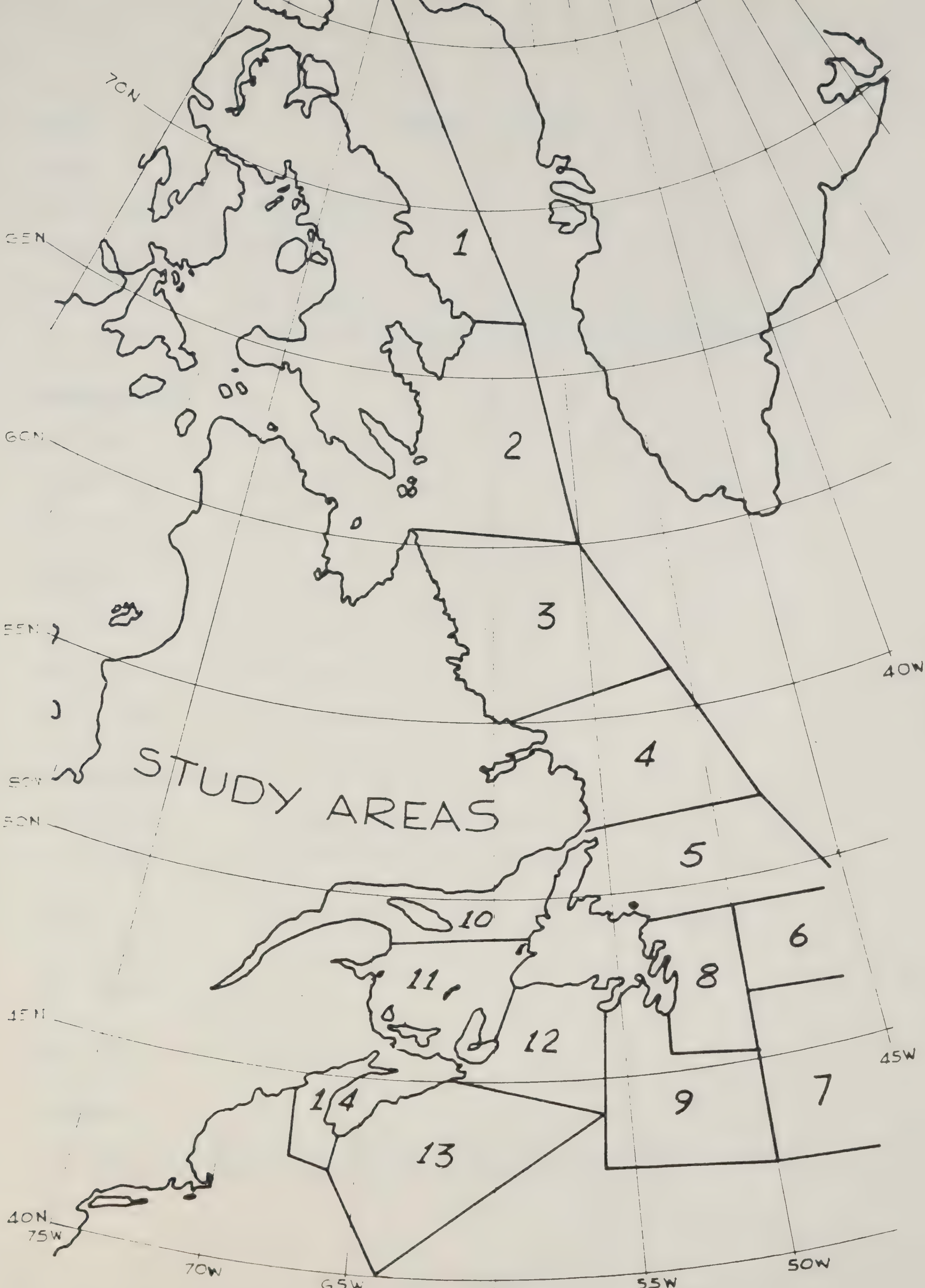
9.9 SUPPLY SHIP

Abandonment and survival systems in supply ships are subject to normal maritime regulations. Providing that sufficient warning is available and acted upon, it is likely that abandonment would be possible in any but the most severe conditions expected off Eastern Canada. It would probably be undertaken by TEMPSC, although inflatable life rafts might be used by some. Survival would be subject to the same limitations as are shown for each of these types of system in Table 8 on page 142. In particular, the survival suits used must take account of the need for supply ship crews to wear them not only during abandonment and survival but also when danger threatens or working on deck in bad weather. Currently available suits do not fulfill the survival criteria as well as providing suitable 'wearability'.

APPENDIX A

Typical Severe Storm Conditions Off Eastern Canada

The typical severe storm conditions likely in the areas off Eastern Canada shown on the enclosed map are listed on the following sheets. These form the basis of the forecasts contained in the main body of the report.



Environmental Areas Off Eastern Canada

AREA 6, 7, 8 **SEASON** Spring

WIND:

GALES DURATION	24-36 hours
STORMS DURATION	12-15 hours
MAX WIND	55-65 knots
DIRECTION	Southeast becoming southwest then northwest

TEMPERATURE:

AVERAGE	4-5
LOWEST	1-2
SEA TEMP	5-6

WAVES:

AVG SIG HT	4 metres
MAX SIG HT	8 metres
MAX HEIGHT	14 metres

CIGS/VISIBILITY:

600ft/2NM	40%-45% rain, fog banks
300ft/½NM	25%-30% rain, snow showers

ICING: Nil in gales, occasional light in storms

ICE BERGS: Likely

SEA ICE: Possible

REMARKS:

Strongest winds are most likely ahead of warm front in south east flow and behind cold front in north west flow.

AREA **9, 12** **SEASON** **Spring**

WIND:

GALES DURATION	30-36 hours
STORMS DURATION	8-12 hours
MAX WIND	55-60 knots
DIRECTION	Southeast becoming northeast then northwest

TEMPERATURE:

AVERAGE	4-6
LOWEST	-1
SEA TEMP	3

WAVES:

AVG SIG HT	3-4 metres
MAX SIG HT	4-5 metres
MAX HEIGHT	8 metres

CIGS/VISIBILITY:

600ft/2NM	40%-45% rain and fog
300ft/½NM	20%-25% rain and fog

ICING: Nil in gales, light in storms

ICE BERGS: Likely

SEA ICE: Nil

REMARKS:

Fetch limitation will cause seas not to build to extremes

AREA **10, 11** **SEASON** **Spring**

WIND:

GALES DURATION	18-24 hours
STORMS DURATION	6-9 hours
MAX WIND	50-55 knots
DIRECTION	Southwest

TEMPERATURE:

AVERAGE	5
LOWEST	1
SEA TEMP	1

WAVES:

AVG SIG HT	2-3 metres
MAX SIG HT	3-4 metres
MAX HEIGHT	7 metres

CIGS/VISIBILITY:

600ft/2NM	35%-40% rain and fog
300ft/½NM	15%-20% rain and fog

ICING: Nil

ICE BERGS: Likely

SEA ICE: Nil

REMARKS:

Seas lower in area 11 due to fetch limitation.

AREA **13, 14** **SEASON** **Spring**

WIND:

GALES DURATION	18-24 hours
STORMS DURATION	6-9 hours
MAX WIND	55-60 knots
DIRECTION	Southeast backing through to northwest

TEMPERATURE:

AVERAGE	6-7
LOWEST	1-2
SEA TEMP	5-6

WAVES:

AVG SIG HT	4 metres
MAX SIG HT	6 metres
MAX HEIGHT	10 metres

CIGS/VISIBILITY:

600ft/2NM	35%-40% rain and fog
300ft/½NM	25%-30% rain and fog

ICING: Nil

ICE BERGS: Nil

SEA ICE: Nil

REMARKS:

Fetch limitations with northerly flow

AREA 1, 2 **SEASON Summer**

WIND:

GALES DURATION	24-30 hours
STORMS DURATION	6 hours
MAX WIND	50-55 knots
DIRECTION	Southeast backing to northwest

TEMPERATURE:

AVERAGE	3-4
LOWEST	-2
SEA TEMP	2

WAVES:

AVG SIG HT	2-3 metres
MAX SIG HT	4-5 metres
MAX HEIGHT	8 metres

CIGS/VISIBILITY:

600ft/2NM	35%-40% rain, snow, fog
300ft/½NM	20%-25% rain, snow, fog

ICING: Occasionally light in gales, light in storms

ICE BERGS: Yes

SEA ICE: Yes

REMARKS:

Wave heights in both areas will be affected by sea ice, more so in area 1.

AREA 3, 4 **SEASON Summer**

WIND:

GALES DURATION	24 hours
STORMS DURATION	6 hours
MAX WIND	50 knots
DIRECTION	East backing to north

TEMPERATURE:

AVERAGE	6-7
LOWEST	2
SEA TEMP	5

WAVES:

AVG SIG HT	3 metres
MAX SIG HT	4 metres
MAX HEIGHT	7 metres

CIGS/VISIBILITY:

600ft/2NM	40%-45% rain and fog
300ft/½NM	15%-20% rain and fog

ICING: Nil

ICE BERGS: Yes

SEA ICE: Likely, especially section 3

REMARKS:

AREA 5 **SEASON Summer**

WIND:

GALES DURATION	12-18 hours
STORMS DURATION	6 hours
MAX WIND	50 knots
DIRECTION	Southeast backing through to north

TEMPERATURE:

AVERAGE	10
LOWEST	6
SEA TEMP	8

WAVES:

AVG SIG HT	3 metres
MAX SIG HT	4 metres
MAX HEIGHT	7 metres

CIGS/VISIBILITY:

600ft/2NM	50% rain and fog
300ft/½NM	25%-30% rain and fog

ICING: Nil

ICE BERGS: Yes

SEA ICE: Possible early in season in northern section

REMARKS:

AREA 6, 7 8 **SEASON Summer**

WIND:

GALES DURATION	18-24 hours
STORMS DURATION	6 hours
MAX WIND	35 knots
DIRECTION	Southeast or northwest

TEMPERATURE:

AVERAGE	12
LOWEST	8
SEA TEMP	12-24

WAVES:

AVG SIG HT	3 metres
MAX SIG HT	5 metres
MAX HEIGHT	8-9 metres

CIGS/VISIBILITY:

600ft/2NM	55%-60% fog and rain
300ft/½NM	35%-40% fog and rain

ICING: Nil

ICE BERGS: Likely

SEA ICE: Nil

REMARKS:

AREA 9, 12 **SEASON Summer**

WIND:

GALES DURATION	12-18 hours
STORMS DURATION	6 hours
MAX WIND	50 knots
DIRECTION	East to northeast

TEMPERATURE:

AVERAGE	12-13
LOWEST	7
SEA TEMP	12

WAVES:

AVG SIG HT	3 metres
MAX SIG HT	4-5 metres
MAX HEIGHT	7-8 metres

CIGS/VISIBILITY:

600ft/2NM	35%-55% fog and rain
300ft/½NM	40%-45% fog and rain

ICING: Nil

ICE BERGS: Possible

SEA ICE: Nil

REMARKS:

Fetch limitation for building seas

AREA **10, 11** **SEASON** **Summer**

WIND:

GALES DURATION	12 hours
STORMS DURATION	4-6 hours
MAX WIND	50 knots
DIRECTION	Southwest

TEMPERATURE:

AVERAGE	13
LOWEST	8
SEA TEMP	10-11

WAVES:

AVG SIG HT	2 metres
MAX SIG HT	3-3½ metres
MAX HEIGHT	6 metres

CIGS/VISIBILITY:

600ft/2NM	45%-50% fog, drizzle
300ft/½NM	25%-30% fog, drizzle

ICING: Nil

ICE BERGS: Likely in area 10

SEA ICE: Nil

REMARKS:

AREA 13, 14 **SEASON Summer**

WIND:

GALES DURATION	12-18 hours
STORMS DURATION	6 hours
MAX WIND	50 knots
DIRECTION	Southeast backing through to northwest

TEMPERATURE:

AVERAGE	16
LOWEST	11
SEA TEMP	13-14

WAVES:

AVG SIG HT	3 metres
MAX SIG HT	4-5 metres
MAX HEIGHT	8 metres

CIGS/VISIBILITY:

600ft/2NM	50%-55% fog
300ft/½NM	30%-35% fog

ICING: Nil

ICE BERGS: Nil

SEA ICE: Nil

REMARKS:

AREA 3, 4 **SEASON Autumn**

WIND:

GALES DURATION	24-30 hours
STORMS DURATION	6-8 hours
MAX WIND	55 knots
DIRECTION	Southeast backing through to north

TEMPERATURE:

AVERAGE	2
LOWEST	-2
SEA TEMP	2-3

WAVES:

AVG SIG HT	4 metres
MAX SIG HT	6 metres
MAX HEIGHT	10 metres

CIGS/VISIBILITY:

600ft/2NM	25%-30% rain, snow and fog banks
300ft/½NM	10%-15% rain, snow and fog banks

ICING: Occasional light in gales, light in storms

ICE BERGS: Yes

SEA ICE: Yes, during last third of season

REMARKS:

AREA 5 **SEASON Autumn**

WIND:

GALES DURATION	18-24 hours
STORMS DURATION	6-9 hours
MAX WIND	50-55 knots
DIRECTION	Southeast backing through to north

TEMPERATURE:

AVERAGE	3-4
LOWEST	-1
SEA TEMP	4

WAVES:

AVG SIG HT	3-4 metres
MAX SIG HT	6 metres
MAX HEIGHT	10 metres

CIGS/VISIBILITY:

600ft/2NM	30% rain/fog banks
300ft/½NM	10%-15% rain/fog banks

ICING: Nil

ICE BERGS: Possible

SEA ICE: Nil

REMARKS:

AREA 6, 7 8 **SEASON Autumn**

WIND:

GALES DURATION	24-36 hours
STORMS DURATION	12-15 hours
MAX WIND	50-60 knots
DIRECTION	Southeast becoming southwest then northwest

TEMPERATURE:

AVERAGE	6
LOWEST	2
SEA TEMP	8

WAVES:

AVG SIG HT	4 metres
MAX SIG HT	8 metres
MAX HEIGHT	14 metres

CIGS/VISIBILITY:

600ft/2NM	45%-50% rain, rainshowers and fog
300ft/½NM	25%-30% rain, rainshowers and fog

ICING: Nil

ICE BERGS: Nil

SEA ICE: Nil

REMARKS:

AREA 9, 12 **SEASON Autumn**

WIND:

GALES DURATION	18-24 hours
STORMS DURATION	9-12 hours
MAX WIND	50-55 knots
DIRECTION	Southeast veering to northwest - area 9 East-southeast backing to north - area 12

TEMPERATURE:

AVERAGE	10
LOWEST	5
SEA TEMP	10-11

WAVES:

AVG SIG HT	3 metres
MAX SIG HT	5 metres
MAX HEIGHT	8 metres

CIGS/VISIBILITY:

600ft/2NM	20%-25% rain and fog banks
300ft/½NM	15%-20% rain and fog

ICING: Nil

ICE BERGS: Nil

SEA ICE: Nil

REMARKS:

Fetch limitation for building seas

AREA 10, 11 **SEASON Autumn**

WIND:

GALES DURATION	18-24 hours
STORMS DURATION	6-9 hours
MAX WIND	50-55 knots
DIRECTION	Southeast veering to west-northwest

TEMPERATURE:

AVERAGE	6-7
LOWEST	1
SEA TEMP	9

WAVES:

AVG SIG HT	2-3 metres
MAX SIG HT	3-4 metres
MAX HEIGHT	7 metres

CIGS/VISIBILITY:

600ft/2NM	40% rain/rainshowers
300ft/½NM	20% rain/rainshowers

ICING: Nil

ICE BERGS: Possible in section 10

SEA ICE: Nil

REMARKS:

AREA 13, 14 **SEASON Autumn**

WIND:

GALES DURATION	18-24 hours
STORMS DURATION	6-9 hours
MAX WIND	55-60 knots
DIRECTION	Southeast veering through to north

TEMPERATURE:

AVERAGE	6-7
LOWEST	2
SEA TEMP	10

WAVES:

AVG SIG HT	4 metres
MAX SIG HT	6 metres
MAX HEIGHT	10 metres

CIGS/VISIBILITY:

600ft/2NM	25% rain/rainshowers
300ft/½NM	15% rain/rainshowers

ICING: Nil

ICE BERGS: Nil

SEA ICE: Nil

REMARKS:

AREA 6. 7 8 **SEASON Winter**

WIND:

GALES DURATION	48 hours
STORMS DURATION	24 hours
MAX WIND	60-70 knots
DIRECTION	Southeast becoming southwest then northwest

TEMPERATURE:

AVERAGE	Near zero
LOWEST	-4 in northwesterlies
SEA TEMP	1

WAVES:

AVG SIG HT	4-5 metres
MAX SIG HT	9-10 metres
MAX HEIGHT	17 metres

CIGS/VISIBILITY:

600ft/2NM	40%-45% rain and snow showers
300ft/½NM	20%-25% rain and snow showers

ICING: Occasional light in gales, severe to very severe in storms

ICE BERGS: Possible

SEA ICE: Possible

REMARKS:

If sea ice present, sea waves will be less

AREA 9, 12 **SEASON Winter**

WIND:

GALES DURATION	30-36 hours
STORMS DURATION	10-15 hours
MAX WIND	55-60 knots
DIRECTION	Southeast becoming northeast then north-northwest

TEMPERATURE:

AVERAGE	-2 to -3
LOWEST	-7
SEA TEMP	1

WAVES:

AVG SIG HT	3-4 metres
MAX SIG HT	4-5 metres
MAX HEIGHT	8-9 metres

CIGS/VISIBILITY:

600ft/2NM	35%-40% snow/snow showers
300ft/½NM	25%-30% snow/snow showers

ICING: Light in gales, severe to very severe in storms

ICE BERGS: Possible in area 9

SEA ICE: Possible in eastern area of 9 and western area of 12

REMARKS:

Fetch limitations will cause seas not to build to extremes

AREA 10, 11 **SEASON Winter**

WIND:

GALES DURATION	24-30 hours
STORMS DURATION	9-12 hours
MAX WIND	55-60 knots
DIRECTION	Southeast veering to northwest in eastern areas. East backing to northwest in western areas.

TEMPERATURE:

AVERAGE	-6
LOWEST	-12
SEA TEMP	0

WAVES:

AVG SIG HT	3 metres
MAX SIG HT	4-5 metres
MAX HEIGHT	7-8 metres

CIGS/VISIBILITY:

600ft/2NM	35%-40% snow/snow showers
300ft/½NM	15%-20% snow/snow showers

ICING: Moderate to severe in gales, very severe in storms

ICE BERGS: Possible

SEA ICE: Likely

REMARKS:

AREA 13, 14 **SEASON Winter**

WIND:

GALES DURATION	36 hours
STORMS DURATION	12 hours
MAX WIND	60-70 knots
DIRECTION	Southeast backing through to northwest

TEMPERATURE:

AVERAGE	Near zero
LOWEST	-4
SEA TEMP	2

WAVES:

AVG SIG HT	4-5 metres
MAX SIG HT	6-7 metres
MAX HEIGHT	12 metres

CIGS/VISIBILITY:

600ft/2NM	35%-40% snow showers/snow
300ft/½NM	25%-30% snow showers/snow

ICING: Occasional light in gales, moderate to severe in storms

ICE BERGS: Nil

SEA ICE: Nil

REMARKS:

Fetch limitation with northerly flow

APPENDIX B

Table of 100 Year Event Values

100 YEAR EVENT

AREA	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Max wind speed in knots	80	80	110	110	120	140	140	140	100	100	100	100	110	110
Sig wave height in metres	7	12	15	15	16	17	17	17	16	10	10	12	15	10
Max wave height in metres	12	20	25	25	26	35	35	35	26	18	18	21	28	18
Min air temperature in celsius	*<-20	*<-20	*<-20	*<-20	*<-20	-26	-26	-26	*<-20	*<-20	*<-20	*<-20	*<-20	*<-20
Min sea temperature in celsius	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	- 2
Ice accumulation from freezing spray expressed in cm/24 hours	> 30	> 30	> 30	> 30	> 30	> 30	> 30	> 30	> 30	> 30	> 30	> 30	> 30	> 30

REMARKS:
1. Maximum wind speed taken from a 10 minute measure
2. Wave heights do not consider shallow water areas
3. *Shows sparse data for region

APPENDIX C

Mean Values of Environmental Conditions

MEAN WIND SPEED IN KNOTS, AND PREVAILING DIRECTION

	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	I/D	I/D	I/D	I/D	I/D	I/D	I/D	N 11	SE 16	NNW 17	I/D	I/D
2	N 22	N 18	N 17	N 16	N 15	E 12	E 11	SE 13	WNW 16	NW 18	NE 19	NNE 19
3	NNW 20	NNW 19	N 17	N 13	NNE 9	NE 12	SW 11	S 12	WNW 16	NW 18	NW 19	NW 19
4	NNW 21	NNW 18	N 19	N 14	NNE 10	NE 13	SW 11	SW 12	W 15	NW 18	NW 20	NW 20
5	WNW 22	WNW 21	NW 19	N 16	NNE 13	WNW 14	SW 12	SW 13	W 15	W 18	W 19	WNW 21
6	W 23	W 23	WNW 20	W 19	W 15	WSW 14	SW 13	WSW 14	W 15	W 18	WSW 19	W 21
7	W 23	W 22	W 20	WSW 19	WSW 15	SW 14	SW 13	WSW 14	W 15	W 18	WSW 19	WSW 21
8	NW 18	WNW 22	NW 19	WNW 17	W 13	WSW 13	SW 12	SW 13	W 14	W 17	WSW 18	W 18
9	WNW 19	W 21	NW 18	NW 16	WSW 13	SW 13	SW 11	SW 13	WSW 13	W 16	WSW 18	W 19
10	NW 18	NW 21	N 18	NNW 13	NE 12	NW 12	W 11	SW 11	WSW 13	WSW 16	W 18	NW 19
11	NW 18	NW 20	NNE 18	N 13	NE 12	WNW 11	W 11	SW 11	SW 12	W 15	W 17	NW 19
12	NW 21	WNW 20	NNW 17	NW 14	WSW 13	WSW 12	SW 11	SW 12	SW 12	W 16	WSW 17	WSW 20
13	NW 18	WNW 19	NNW 16	NW 16	WSW 13	WSW 11	SW 10	SW 11	SW 12	WNW 15	WSW 17	WNW 20
14	NW 16	WNW 18	N 18	NW 13	W 13	W 10	SW 9	WSW 9	WSW 11	WNW 13	WNW 16	NW 18

MEAN AIR TEMPERATURE, DEGREES CELSIUS

	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	I/D	I/D	I/D	-10	-7	-1	3	3	1	-4	-9	-14
2	I/D	I/D	I/D	-6	0	4	5	4	3	0	-4	-8
3	-7	-7	-5	-3	1	5	7	7	5	1	-1	-5
4	-5	-6	-3	-2	1	5	8	9	7	3	0	-3
5	-4	-5	-2	-1	3	6	10	12	10	5	2	-1
6	-2	-2	0	2	4	7	11	14	12	9	6	2
7	0	-1	1	2	5	8	12	15	14	10	8	4
8	-1	-2	-1	1	3	7	11	14	12	8	5	1
9	-1	-3	-1	1	4	8	13	15	14	10	6	3
10	-6	-7	-3	0	4	9	12	15	12	7	3	0
11	-5	-5	-3	1	6	11	14	17	13	9	4	1
12	-3	-4	-3	1	5	9	14	17	14	10	5	2
13	1	0	0	3	6	11	16	17	15	11	7	3
14	-1	-2	0	3	7	12	16	16	14	10	6	3

MEAN AIR TEMPERATURE, DEGREES CELSIUS

	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	I/D	I/D	I/D	-10	-7	-1	3	3	1	-4	-9	-14
2	I/D	I/D	I/D	-6	0	4	5	4	3	0	-4	-8
3	-7	-7	-5	-3	1	5	7	7	5	1	-1	-5
4	-5	-6	-3	-2	1	5	8	9	7	3	0	-3
5	-4	-5	-2	-1	3	6	10	12	10	5	2	-1
6	-2	-2	0	2	4	7	11	14	12	9	6	2
7	0	-1	1	2	5	8	12	15	14	10	8	4
8	-1	-2	-1	1	3	7	11	14	12	8	5	1
9	-1	-3	-1	1	4	8	13	15	14	10	6	3
10	-6	-7	-3	0	4	9	12	15	12	7	3	0
11	-5	-5	-3	1	6	11	14	17	13	9	4	1
12	-3	-4	-3	1	5	9	14	17	14	10	5	2
13	1	0	0	3	6	11	16	17	15	11	7	3
14	-1	-2	0	3	7	12	16	16	14	10	6	3

AVERAGE ICE COVERAGE IN TENTHS

	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	10	10	10	10	8	5	3	2	3	8	10	10
2	9	10	10	8	7	6	6	1	1	0	4	7
3	7	10	10	9	7	6	3	0	0	0	0	5
4	6	8	8	7	6	4	0	0	0	0	0	2
5	4	6	7	5	3	2	0	0	0	0	0	1
6	1	2	3	1	TR	TR	0	0	0	0	0	0
7	0	0	1	1	0	0	0	0	0	0	0	0
8	1	3	4	2	1	TR	0	0	0	0	0	0
9	0	TR	TR	TR	0	0	0	0	0	0	0	0
10	6	7	8	5	2	1	0	0	0	0	0	2
11	3	5	8	3	TR	0	0	0	0	0	0	0
12	1	2	2	1	TR	0	0	0	0	0	0	0
13	0	TR	TR	TR	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0

MEAN SIGNIFICANT WAVE HEIGHTS IN METRES

	JAN	FEB	MARCH	APRIL	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	ICE	ICE	ICE	ICE	ICE	ICE	0.8	1.0	1.5	ICE	ICE	ICE
2	ICE	ICE	ICE	ICE	ICE	1.0	1.0	1.5	2.0	2.0	2.0	ICE
3	ICE	ICE	ICE	ICE	ICE	1.0	1.0	1.5	2.0	2.0	2.0	2.0
4	ICE	ICE	ICE	ICE	ICE	1.5	1.5	1.5	2.0	2.0	2.0	2.5
5	2.0	2.5	ICE	2.0	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.5
6	3.0	3.0	2.5	2.0	2.0	2.0	1.5	1.5	2.0	2.0	2.5	2.8
7	3.0	3.0	2.5	2.0	2.0	2.0	1.5	1.5	2.0	2.0	2.5	2.8
8	2.0	2.5	2.0	1.5	1.5	1.5	1.5	1.5	2.0	2.0	2.0	2.5
9	2.0	2.5	2.0	1.5	1.5	1.5	1.0	1.5	2.0	2.0	2.0	2.5
10	ICE	ICE	ICE	1.5	1.5	1.0	1.0	1.5	2.0	2.0	2.0	2.2
11	1.5	1.5	ICE	1.0	1.0	0.8	0.7	1.0	1.5	2.0	2.0	2.0
12	1.5	2.0	1.5	1.0	1.0	1.0	1.0	1.5	1.5	2.0	2.0	2.2
13	1.5	2.0	2.0	1.5	1.0	1.0	1.0	1.5	1.5	2.0	2.0	2.3
14	1.0	1.5	1.5	1.5	1.0	0.8	0.8	1.0	1.0	1.5	2.0	2.0